Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2019

PHYSICS AND CHEMISTRY – HIGHER LEVEL

WEDNESDAY, 19 JUNE – MORNING, 9:30 to 12:30

Six questions to be answered.

Answer any **three** questions from **Section I** and any **three** questions from **Section II**.

All questions carry equal marks.

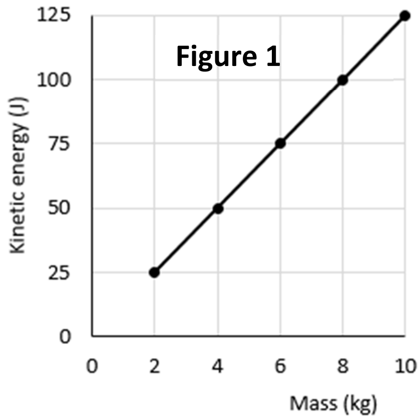
However, in each section, one additional mark will be given to each of the first two questions for which the highest marks are obtained.

N.B. Relevant data are listed in the *Formulae and Tables* booklet, which is available from the superintendent. Take g = 9.8 m s^{-2} as the acceleration due to gravity at the surface of the Earth.

SECTION I – PHYSICS (200 marks)

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

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



(*b*) **Figure 1** represents the kinetic energies of different masses travelling at the same velocity. What is this velocity?

(*c*) An object, starting from rest, travels under constant acceleration of 8 m s^{-2}.
How long does it take to cover the first 144 m?

(*d*) Under what condition is momentum conserved in a system of colliding bodies?

(*e*) Write down two properties of an image formed by a plane mirror.

(*f*) Calculate the focal length of a convex security mirror like that shown in **Figure 2** if the image of a person 300 cm from the mirror is formed 50 cm behind the mirror.

Figure 2

(*g*) Name the phenomenon where small visible particles suspended in a gas or liquid are observed to be in constant, random motion.
What does this phenomenon indicate about the behaviour of the *molecules* of the gas or liquid?

(*h*) State Boyle's law.

(*i*) What is meant by a thermometric property?
On what thermometric property is a liquid-in-glass thermometer based?

(*j*) A transformer for a toy electric railway operates from the 230 V a.c. mains supply and has a 12.0 V a.c. output.
The secondary coil has 960 turns.
Calculate the number of turns in the primary coil.

(*k*) **Figure 3** shows that a 'three-way' bulb used to produce different brightness levels of light has two filaments, R_1 and R_2.
R_1 = 480 Ω and R_2 = 960 Ω.
Calculate the total resistance of this arrangement of R_1 and R_2 when both switches are closed.

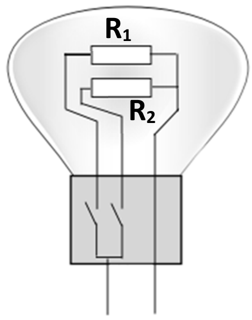


Figure 3

(*l*) Give one application of a capacitor in an electrical circuit.

(*m*) Why are high voltages used to transmit electricity over long distances?

(*n*) When a radioisotope emits an alpha particle the new nucleus produced is polonium–218.
Identify the radioisotope.

(*o*) Define the half-life of a radioactive isotope.

(11 × 6)

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

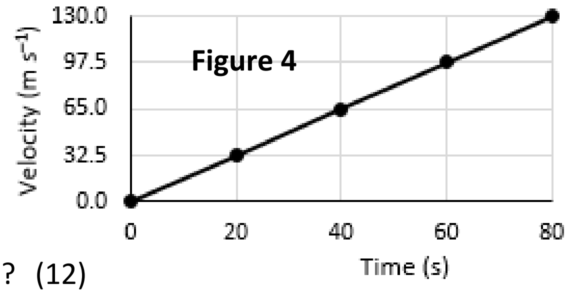
(*ii*) What quantity is defined as the rate of change of velocity?

(*iii*) What is the S.I. unit of measurement of the quantity in (*ii*)? (12)

(*b*) (*i*) Write an equation to show the relationship between G, the gravitational constant and g, the acceleration due to gravity at a particular location.

(*ii*) Why do the values of g at the surfaces of the Earth and the Moon differ? (12)

(*c*) **Figure 4** shows how the velocity of an object changed with time when dropped onto the surface of the Moon.



(*i*) Use the graph to estimate a value for g_m, the acceleration due to gravity at the surface of the Moon.

(*ii*) How far did the object fall in the first 40 s? (12)

(*d*) (*i*) Draw a labelled diagram of an arrangement of apparatus you used to determine g_e, the acceleration due to gravity at the Earth's surface.

(*ii*) What two quantities did you measure during the experiment?

(*iii*) State two precautions taken to ensure an accurate result.

(*iv*) Write the equation you used to calculate g_e.

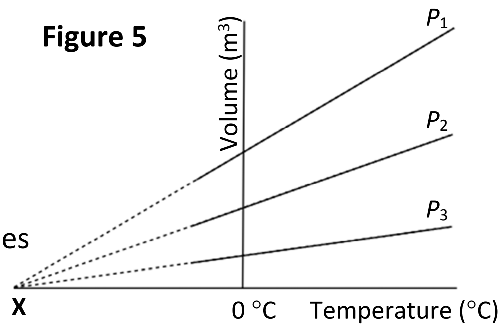
(*v*) If measurements using the apparatus in (*d*) (*i*) could also be taken on the Moon, give a reason why the value of g_m obtained would be more accurate than the value calculated for g_e. (30)

3. (*a*) (*i*) What is meant by the term *ideal gas*?

(*ii*) Under what conditions does a real gas most resemble the ideal gas?

(*iii*) Why does a real gas most resemble the ideal gas under these conditions? (18)

Figure 5 shows how the volume of a fixed mass of a gas varies with temperature at different pressures, P_1, P_2 and P_3.



(*b*) (*i*) What is the exact value of **X** in °C?

(*ii*) What is the significance of this temperature? (9)

(*c*) Which of P_1, P_2 or P_3 is the highest pressure? Justify your answer. (9)

(*d*) (*i*) Sketch the graph you would expect to obtain if the volume of the gas was plotted against absolute temperature at one of these pressures.

(*ii*) Name and state the law illustrated by your graph. (15)

(*e*) An elastic balloon containing helium gas had a volume of 0.060 m^3 at sea level where the pressure was 99 kPa and the temperature was 22 °C. The balloon was released and rose through the atmosphere until the pressure was 50 kPa and the temperature was –31 °C. Assuming no helium leaked out and the balloon did not burst, calculate

(*i*) the number of moles of helium in the balloon,

(*ii*) the final volume of the balloon. (15)

4. (*a*) Define (*i*) the refractive index, (*ii*) the critical angle, of a material. (12)

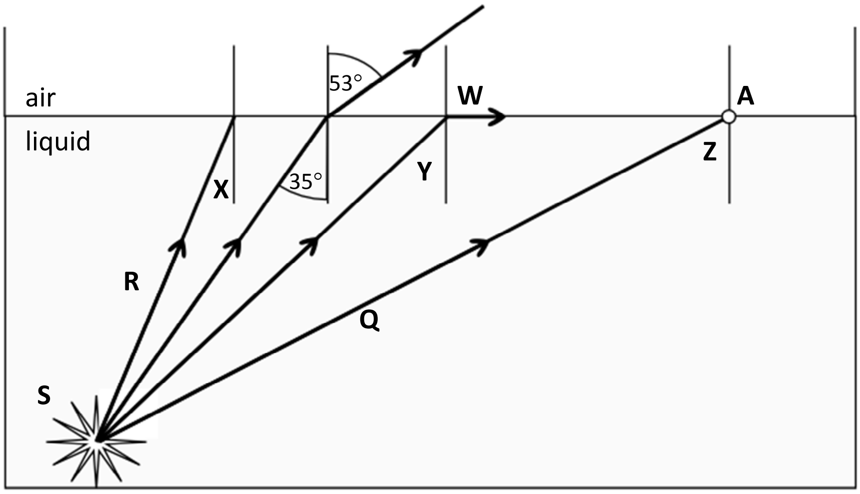


Figure 6

(*b*) **Figure 6** shows rays of light from source **S** striking a liquid-air boundary.

(*i*) Calculate the refractive index of the liquid. (6)

(*ii*) Explain which of the angles, **W**, **X**, **Y** or **Z** is the critical angle. (6)

(*iii*) Copy the diagram and complete it to show the paths of rays **R** and **Q** after striking the boundary. (12)

(*iv*) Name the phenomenon that occurs at the point marked **A**. (6)

(*c*) The refractive index of the same liquid was also determined from the measurements of the angles of incidence *i* and the corresponding angles of refraction *r* for a ray of light entering a transparent, thin-walled container of the liquid, as shown in **Figure 7**.

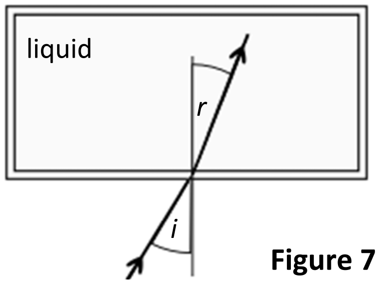


Figure 7

These measurements are given in the table.

i (°)	0	20	30	40	50	60	70
sin i	0	0.34	0.50	0.64	0.77	0.87	0.94
r (°)	0	14	21	27	34	39	43
sin r	0						

(*i*) Copy and complete the last row of the table with sin r values correct to two decimal places.

(*ii*) Draw a graph of sin i *versus* sin r (x-axis).

(*iii*) What is the relationship between sin i and sin r shown in your graph?

(*iv*) How can the refractive index of the liquid be determined from the graph? (24)

5. (*a*) State Ohm's law. (6)

(*b*) The circuit shown in **Figure 8** was used to investigate whether the wire filament **F** obeys Ohm's law.

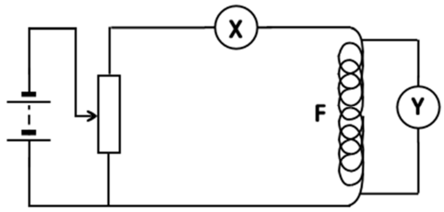


Figure 8

(*i*) Name the meters **X** and **Y**.

(*ii*) How was this circuit used to investigate whether the wire filament obeys Ohm's law?

(*iii*) Explain which of the graphs, **A**, **B** or **C**, of current *I versus* voltage *V* shown in **Figure 9**, would confirm that the wire filament does obey Ohm's law. (24)

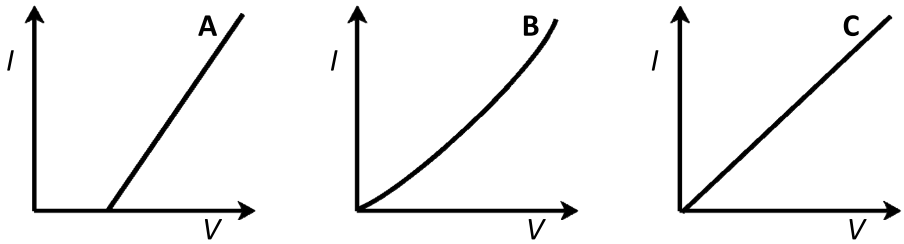


Figure 9

(*c*) Calculate

(*i*) the current flowing in a 100 W bulb when connected to a 230 V supply,

(*ii*) the resistance of the bulb when this current flows. (12)

(*d*) **Figure 10** shows the internal structure of a simple dynamo, a direct current (d.c.) generator.

(*i*) Name **A** and **B**.

(*ii*) State the principle of operation of a dynamo.

(*iii*) What is the main energy conversion that takes place when a dynamo operates?

(*iv*) Sketch a graph to show how the output voltage (e.m.f.) of a dynamo varies with time. (24)

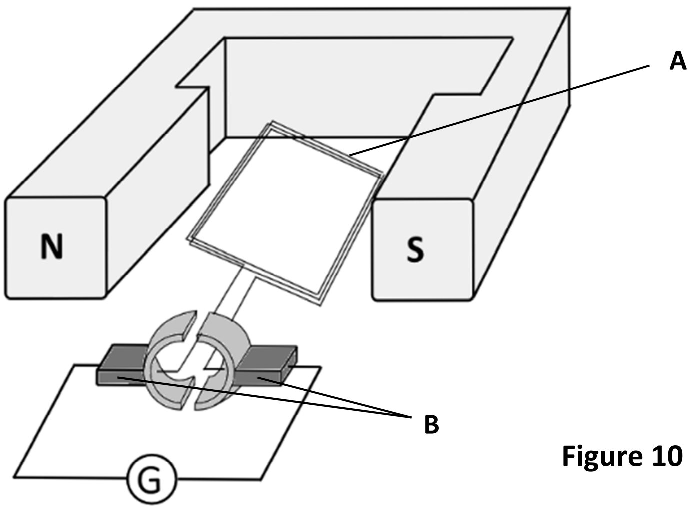


Figure 10

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

(*a*) Define (*i*) work, (*ii*) power.

Which of the following are vector quantities?

displacement **mass** **energy** **force** **power**

As an object falls towards the surface of the Earth, what is the relationship between its potential energy and its kinetic energy? (18)

An athlete lifted a mass vertically through 60 cm in 0.2 s using a weights machine in a gym. The athlete's average power output was 588 W. Calculate

(*iii*) the work done on the mass,

(*iv*) the average force applied to the mass,

(*v*) the mass lifted. (15)

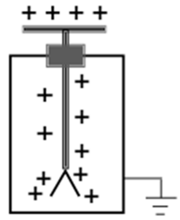


Figure 11

(*b*) What is the S.I. unit of measurement of electrical charge?

Describe and explain what happens when each of the following is brought near the cap of a *positively*-charged electroscope like that shown in **Figure 11**:

(*i*) a positively-charged plastic rod,

(*ii*) a negatively-charged plastic rod,

(*iii*) an uncharged plastic rod. (21)

Describe how an electroscope can be used to distinguish between an insulating rod and a conducting rod.

What happens when a person touches the cap of a positively-charged electroscope? (12)

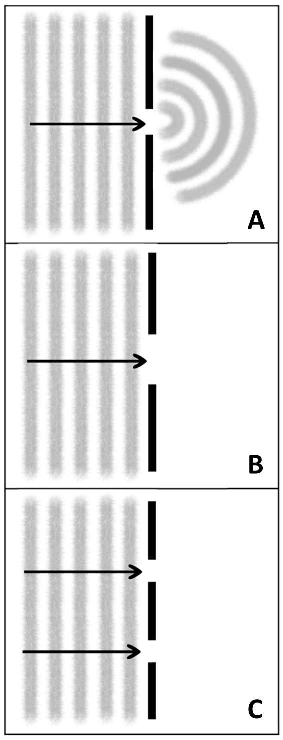


Figure 12

(*c*) Define (*i*) wavelength, (*ii*) frequency, of a light wave.

Calculate the wavelength of an ultraviolet wave whose photons have an energy of 2.0×10^{-18} J. (21)

Study **Figure 12** and

(*iii*) name the wave phenomenon illustrated in **A**,

(*iv*) copy part **B** and complete it to show the wavefront having passed through a wider slit than it does in **A**,

(*v*) name another phenomenon that occurs when waves pass simultaneously through two slits as shown in **C**. (12)

(*d*) Identify $\mathbf{X}$, $\boldsymbol{y}$ and $\boldsymbol{z}$ in the nuclear reaction:

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{140}_{54}\mathrm{Xe} + {}^{y}_{z}\mathrm{X} + 2{}^{1}_{0}n + \text{energy}$$

Identify the type of nuclear reaction involved.

Explain what is meant by mass-energy conservation. (18)

Consider the following nuclear reaction: ${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}n + \text{energy}$

(*i*) Take the mass of a neutron as 1.008664 u and data from page 83 of the *Formulae and Tables* booklet to calculate the mass loss (in u) in this reaction.

(*ii*) Use data from page 47 of the *Formulae and Tables* booklet to calculate the energy (in J) released in this reaction. (15)

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*) Identify the *ion* that has 16 protons and 18 electrons.

(*b*) What are isotopes?

(*c*) Write an equation for the relationship between the frequency of a line in the hydrogen emission spectrum and two of the main energy levels in a hydrogen atom.

(*d*) What name is given to the amount of a compound that contains its relative molecular mass in grams?

(*e*) Calculate the molarity of a sodium carbonate solution containing 13.25 g $\mathbf{Na_2CO_3}$ in 250 cm^3 of solution.

(*f*) $\mathbf{H_2S}$ has a permanent dipole moment; $\mathbf{CO_2}$ has no permanent dipole moment. What is the shape of (*i*) a $\mathbf{H_2S}$ molecule, (*ii*) a $\mathbf{CO_2}$ molecule?

(*g*) Find by calculation the chemical formula of the chloride of phosphorus ($\mathbf{PCl_x}$) that contains 77.5% by mass of chlorine.
(**P** = 31, **Cl** = 35.5)

(*h*) A wooden splint, soaked in water overnight, is dipped in a salt and then held in a Bunsen flame as shown in **Figure 13**.
(*i*) What colour is observed when the salt is **NaCl**?
(*ii*) What metal is present in the salt when a purple flame is observed?

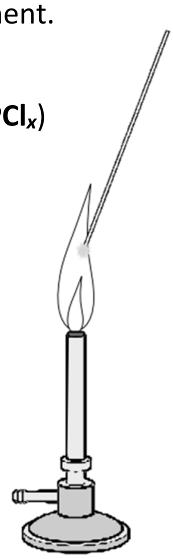


Figure 13

(*i*) What volume is occupied by 51 g of ammonia ($\mathbf{NH_3}$) gas at s.t.p.?

(*j*) Limewater is a saturated solution of calcium hydroxide formed when calcium oxide is added to water.
(*i*) Is limewater acidic or basic?
(*ii*) Write the chemical formula for calcium hydroxide.

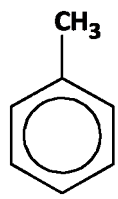
(*k*) Define heat of combustion.

(*l*) Write a balanced equation for the complete combustion of $\mathbf{C_2H_2}$ in oxygen, the reaction that produces an oxyacetylene welding flame.

(*m*) Why is excessive burning of hydrocarbon fuels by humans harmful to the environment?

(*n*) (*i*) Name the organic compound whose molecular structure is shown in **Figure 14**.
(*ii*) What is its molecular formula?

Figure 14



(*o*) Give the systematic IUPAC name *or* draw the structure of the ester formed in the reaction between methanol and ethanoic acid.

(11 × 6)

8. (*a*) Define (*i*) atomic number, (*ii*) mass number. (6)

(*b*) State and explain the trend in atomic radii down Group 1 in the periodic table. (9)

(*c*) What is meant by the *first ionisation energy* of an element? (9)

(*d*) Define an atomic orbital.

Write the (*s*, *p*, etc) electron configuration for (*i*) neon, (*ii*) bromine.

How many atomic orbitals are occupied by electrons in a neon atom? (18)

(*e*) The reactivity of an element is determined by the number and arrangement of electrons around the nucleus of each of its atoms.
Figure 15 shows sodium metal reacting violently with water.

Figure 15

Explain why

(*i*) the alkali metal, sodium, is so reactive,

(*ii*) the alkali metals become *more* reactive down their group in the periodic table,

(*iii*) bromine is *less* reactive than chlorine,

(*iv*) neon is chemically inert. (15)

(*f*) (*i*) How is an ionic bond formed between a pair of atoms?

(*ii*) How is a double covalent bond formed between a pair of atoms? (9)

9. (*a*) (*i*) Define pH.

(*ii*) Calculate the pH of a 0.30 M sodium hydroxide (**NaOH**) solution. (12)

(*b*) (*i*) Distinguish between a strong acid and a weak acid.

(*ii*) What is the conjugate base of an acid represented by **HX**? (9)

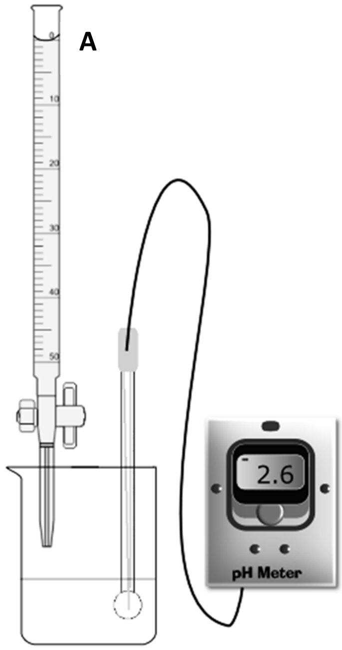


Figure 16

A 0.30 M solution of **NaOH** was titrated against 20.0 cm^3 of a solution of acid **HX** using the apparatus shown in **Figure 16**. The balanced equation for the reaction that occurred is:

$$\mathbf{HX + NaOH \rightarrow NaX + H_2O}$$

A number of pH readings, and the corresponding volumes of **NaOH** solution added to the acid in the beaker, are shown in the table.

Volume **NaOH** (cm^3)	pH
0	2.6
2.0	3.7
4.0	4.1
8.0	4.5
14.0	5.0
18.0	5.5
20.0	5.9
20.9	6.4
21.3	8.1
21.4	10.7
21.6	11.3
22.0	11.7
23.0	12.1
28.0	12.6
36.0	12.9
40.0	13.0

(*c*) (*i*) Name the piece of equipment **A** used to add the **NaOH** solution to the acid.

(*ii*) Describe how **A** was rinsed before use. (9)

(*d*) Draw a graph of pH (*y*-axis) against the volume of **NaOH** added. (12)

(*e*) The end point of the titration corresponds to the sharp rise in pH on the graph.

(*i*) Read from your graph the volume of **NaOH** added to the acid at the end point.

(*ii*) Use this reading and the information given above to calculate the concentration of the acid **HX** in moles per litre. (9)

(*f*) (*i*) Use the pH at the end point to deduce whether **HX** is a strong or a weak acid.

Justify your answer.

(*ii*) Suggest a suitable acid-base indicator to detect the end point of this titration by a colour change.

(*iii*) State the colour change observed at the end point if a few drops of this indicator had been added into the beaker at the start. (15)

10. (*a*) Iron(III) oxide and aluminium react together rapidly and exothermically in the *thermite* reaction according to the following balanced equation.

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$$

The molten iron produced can be used to weld sections of railway track together.

(*i*) Define oxidation.

(*ii*) Which substance is oxidised in the thermite reaction?

(*iii*) Identify the species that loses electrons in the reaction.

(*iv*) Identify the oxidising agent in the reaction. (15)

(*b*) (*i*) List **Cu**, **Pb**, **Al**, **Fe**, **K** and **Au** in order of decreasing ease of oxidation.

(*ii*) Which one of these metals has the most heat-stable oxide? Justify your answer.

(*iii*) Explain whether copper(II) sulfate crystals should be stored in an aluminium container.

(*iv*) What is *corrosion* of a metal?

(*v*) How *and* why do the resistances to corrosion of iron and aluminium differ? (30)

(*c*) (*i*) Describe with the aid of a labelled diagram how you could demonstrate the electrolysis of molten lead bromide (**$PbBr_2$**) (m.p. 373 °C) using inert electrodes.

(*ii*) Why must the **$PbBr_2$** be molten?

A current of 1.5 A flowed for 12 minutes through a sample of molten **$PbBr_2$**.

(*iii*) What quantity of charge flowed?

(*iv*) What mass of lead was formed? (21)

11. Consider the hydrocarbons **X** = **C_4H_{10}**, **Y** = but-2-ene and **Z** = **C_6H_6**.

(*a*) (*i*) What is a hydrocarbon?

What is an *unsaturated* hydrocarbon?

(*ii*) Give the IUPAC names for **X** and **Z**.

Draw a structure for **Y**.

Why should **Z** not be used in a school laboratory? (21)

(*b*) A few drops of dilute, acidified **$KMnO_4$** are shaken in a test-tube containing (*i*) **X**, (*ii*) **Y**. State and explain what is observed in each case. (12)

(*c*) Name the main organic product of the reaction between

(*i*) **Br_2** and but-2-ene,

(*ii*) **Br_2** and **C_6H_6**.

Classify each of these reactions as an addition or a substitution reaction.

Which one of these reactions occurs only very slowly without a catalyst?

Identify the catalyst involved. (18)

(*d*) What is a functional group?

What is a homologous series?

Draw the structure of the second member of the aldehyde homologous series showing all of its bonds. (15)

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

(*a*) Ozone (**O_3**) and oxygen (**O_2**) are allotropes.

(*i*) Define the underlined term.

O_3 at ground level is one of the main causes of the photochemical smog shown in **Figure 17**. Ozone detector strips are pieces of paper containing chemicals that react with **O_3** to form **I_2** according to the balanced equation:

Figure 17

$$O_3\,(g) + 2KI\,(aq) + H_2O\,(l) \rightarrow O_2\,(g) + 2KOH\,(aq) + I_2\,(aq)$$

Indicators in the paper darken in the presence of **I_2** and the colour intensity of the paper after 20 minutes is related to the **O_3** concentration in the air. Calculate

(*ii*) the number of moles of **O_3** absorbed by a test paper if 6.35×10^{-4} g **I_2** was formed,

(*iii*) the number of *atoms* of oxygen in this quantity of **O_3**,

(*iv*) the number of moles of **KI** in the 1.0 cm^3 of the 0.025 M solution of **KI** absorbed by the paper during manufacture of each test strip.

(*b*) Nickel is a transition element; its metallic crystalline structure is shown in **Figure 18**.

Explain the underlined term.

Give two characteristic properties of transition metal compounds.

What is a crystal?

Describe the bonding in a metallic crystal like nickel.

Would you expect nickel to be a good electrical conductor? Explain.

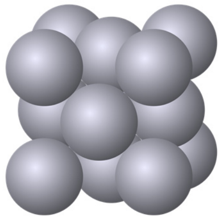


Figure 18

(*c*) State Hess's law.

Hydrogen cyanide (**HCN**), a poisonous substance important in the polymer industry, is synthesised from methane and ammonia by the following reaction.

$$CH_4\,(g) + NH_3\,(g) \rightarrow HCN\,(g) + 3H_2\,(g)$$

Calculate the heat change for this reaction given the following information:

$$N_2\,(g) + 3H_2\,(g) \rightarrow 2NH_3\,(g) \qquad \Delta H = -91.8 \text{ kJ}$$

$$C\,(s) + 2H_2\,(g) \rightarrow CH_4\,(g) \qquad \Delta H = -74.9 \text{ kJ}$$

$$2C\,(s) + H_2\,(g) + N_2\,(g) \rightarrow 2HCN\,(g) \qquad \Delta H = 270.3 \text{ kJ}$$

Is the reaction of methane with ammonia exothermic or endothermic?

Give one use for the **H_2** gas, the co-product of this **HCN** synthesis.

(*d*) Define electronegativity.

Explain how electronegativity values can be used to predict

(*i*) whether an ionic compound is formed when two elements react,

(*ii*) the polarity of a single covalent bond formed between two atoms.

Draw a dot and cross diagram to show the bonding in a molecule of tetrachloromethane (**CCl_4**).

Why is the **CCl_4** molecule non-polar while the **C–Cl** bonds it contains are slightly polar?

Explain whether you would expect **CCl_4** to be water soluble.

Leaving Certificate – Higher Level

Physics and Chemistry

Wednesday, 19 June

Morning, 9:30 – 12:30

Image Q1(*f*) on page 2: from visionmetalizers.com, accessed 18 October 2018

Image Q8 on page 8: Tavoromann, from commons.wikimedia.org/wiki/
File: Naatriumi reaktsioon veega purustab klaasist anuma.jpg, accessed 18 October 2018, CC-BY-SA-3.0

Image Q12(*a*) on page 11: Tae Fuller from www.pexels.com
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