Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION

CHEMISTRY – HIGHER LEVEL

3 HOURS DURATION

300 MARKS

Answer any **six** questions.

All questions carry equal marks (50).

The information below should be used in your calculations.

Relative atomic masses (rounded): H = 1.0, C = 12, N = 14, O = 16, S = 32, Ca = 40, Fe = 56, Zn = 65

Molar volume at s.t.p. = 22.4 litres

Universal gas constant, R = 8.3 J K^{-1} mol^{-1}

Avogadro constant = 6.0×10^{23} mol^{-1}

Ionic product (dissociation constant) of water, $K_w = 1.0 \times 10^{-14}$ mol^2 l^{-2} at 25 °C

The use of the *Formulae and Tables* booklet approved for use in the State Examinations is permitted. A copy may be obtained from the superintendent.

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Section A

See page 1 for instructions regarding the number of questions to be answered.

1. Ammonium iron(II) sulfate crystals are used in lawn feed.

To analyse the iron(II) content of ammonium iron(II) sulfate crystals, 11.76 g of the crystals were used to make up 250 cm^3 of solution. The ammonium iron(II) sulfate crystals were first dissolved in about 30 cm^3 of dilute sulfuric acid in a small beaker. This solution was then carefully transferred to a 250 cm^3 volumetric flask and the solution was made up to the mark using deionised water.

The resulting iron(II) solution was measured in 25.0 cm^3 portions into a conical flask, about 15 cm^3 of dilute sulfuric acid were added and the mixture was then titrated with a previously standardised 0.020 M solution of potassium manganate(VII) (**$KMnO_4$**).

(*a*) How could you ensure that all the solution was transferred from the small beaker to the volumetric flask? (8)

(*b*) Describe the procedure for washing and filling a burette with the potassium manganate(VII) solution. (12)

(*c*) Why was dilute sulfuric acid added to the iron(II) solution in the conical flask before the titrations were commenced? (6)

(*d*) How was the end point detected? (6)

The titration reaction is described by the equation:

$$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

(*e*) In the titrations, 25.0 cm^3 portions of the iron(II) solution made from the crystals required 30.0 cm^3 of the 0.020 M **$KMnO_4$** solution for complete reaction.

Calculate

(*i*) the concentration of the solution in the volumetric flask in moles per litre of iron(II),

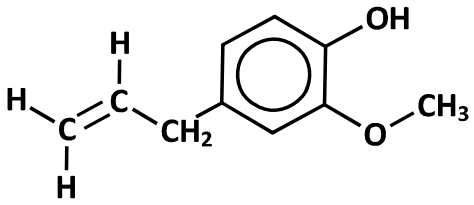
(*ii*) the mass of iron(II) in the 11.76 g of crystals used to make up the 250 cm^3 of solution,

(*iii*) the percentage by mass of iron(II) in the crystals. (18)

2. Eugenol (boiling point 254 °C) is a heat sensitive substance that can be extracted from cloves as the major component of clove oil using steam distillation. The distillate produced consists of an emulsion of clove oil and water.

Liquid-liquid extraction is then used to isolate the clove oil from the distillate.

The structural formula of eugenol is shown.



(*a*) Copy the structure of eugenol and identify clearly

(*i*) a carbon atom in tetrahedral geometry,

(*ii*) a site where you would expect addition reactions could easily occur. (8)

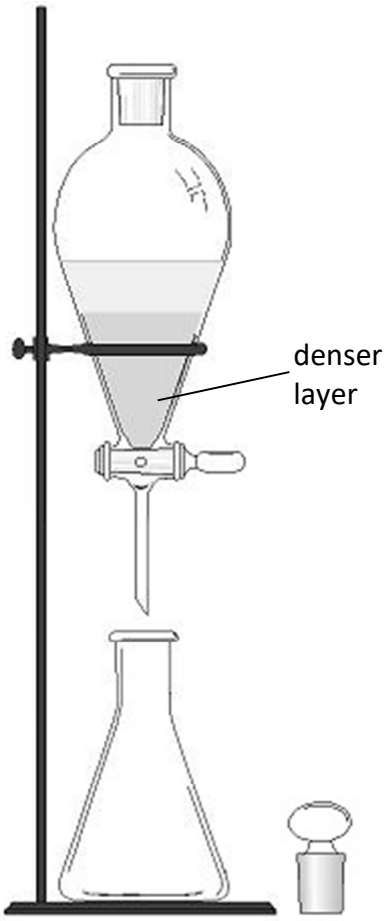
(*b*) Explain the underlined term.

Describe the appearance of the distillate. (6)

(*c*) Explain why ethanol is an unsuitable solvent for use in the liquid-liquid extraction of the clove oil from the distillate.

Name a suitable organic solvent for this liquid-liquid extraction of the clove oil.

State whether the aqueous layer is denser or less dense than the organic layer. (9)



(*d*) Give a reason why, during the liquid-liquid extraction,

(*i*) the distillate is washed three separate times, using 10 cm^3 of solvent each time, instead of once with 30 cm^3 of solvent,

(*ii*) the tap of the stoppered separating funnel is opened briefly with the funnel lying on its side or upside down. (6)

(*e*) Having separated the aqueous and organic layers into two separate flasks, describe how a dry sample of clove oil is then obtained. (12)

(*f*) What volume of dry clove oil (density 1.05 g cm^{-3}) is obtained from exactly 12 g of cloves using steam distillation followed by liquid-liquid extraction given the percentage yield for the overall process is 7% by mass? (6)

(*g*) Give a commercial use for clove oil. (3)

3. A group of students carried out an experiment to investigate the rate of decomposition of hydrogen peroxide in the presence of a catalyst.

The reaction is described by the following equation.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Time (minutes)	0	1	2	3	4	5	6	7	8
Volume O_2 at s.t.p. (cm^3)	0	20	35	46	53	57	59	60	60

(*a*) Draw a labelled diagram of an apparatus that could have been used in this experiment.

How could the catalyst and the hydrogen peroxide have been combined without affecting the volume of gas collected? (11)

(*b*) Identify a transition metal catalyst that could have been used when carrying out this experiment.

What type of catalysis is involved in this reaction?

Explain your answer. (9)

(*c*) Draw a graph of volume (*y*-axis) against time using the results obtained by the students. (12)

(*d*) Use the graph to determine

(*i*) the time required to produce 0.00116 moles of oxygen,

(*ii*) the instantaneous rate of the reaction at 4.5 minutes. (12)

(*e*) Mark clearly on your graph the approximate curve you would expect to plot if this experiment were repeated using the same mass of the same catalyst and a solution of the same volume, but this time exactly half the concentration, of the original hydrogen peroxide solution. (6)

Section B

See page 1 for instructions regarding the number of questions to be answered.

4. Answer **eight** of the following (*a*), (*b*), (*c*), etc. (50)

(*a*) How did Mendeleev arrange the elements to form his periodic table?

(*b*) The dispositive ion $\mathbf{M^{2+}}$ has 28 electrons and 34 neutrons. What is

(*i*) the atomic number,

(*ii*) the mass number, of **M**?

(*c*) What is the oxidation number of sulfur in

(*i*) $\mathbf{SO_2}$

(*ii*) $\mathbf{H_2SO_4}$?

(*d*) How many atoms are there in 448 cm^3 of carbon dioxide measured at s.t.p.?

(*e*) Under what conditions do gases come closest to ideal behaviour?

(*f*) Calculate the molarity of a 3% (w/v) solution of ethanoic acid ($\mathbf{CH_3COOH}$).

(*g*) State Avogadro's law.

(*h*) Draw the structural formula of

(*i*) 2,2-dimethylpropane,

(*ii*) ethylbenzene.

(*i*) What is the principle involved in separating a mixture by chromatography?

(*j*) Identify an organic compound responsible for

(*i*) the sting of nettles,

(*ii*) the smell of almonds.

(*k*) Write the chemical formulae for:

(*i*) silicon chloride,

(*ii*) manganese(III) oxide.

This question continues on the next page.

(*l*) Answer part **A** *or* part **B**.

A Describe with the aid of a balanced equation how atmospheric nitrogen gas is fixed by lightning.

or

B How does a sacrificial anode protect a piece of metal from corrosion?

5. (*a*) The existence of electrons was first shown in experiments on cathode rays.

(*i*) Who coined the name '*electron*'? (5)

(*ii*) What were the contributions of Thomson and Millikan to our understanding of electrons? (12)

(*iii*) Give the electronic configuration (*s*, *p*, etc) of copper in its ground state. (6)

(*iv*) How are the electrons arranged in the orbitals of the highest occupied sub-level of a nitrogen atom in its ground state? (6)

(*b*) Electrons are emitted by some radioactive substances.

(*i*) What name is given to the type of nuclear radiation involving the release of electrons?

Compare the penetrating power of this type of radiation with the penetrating powers of the other forms of radiation emitted by radioactive substances. (9)

(*ii*) The emission of electrons by carbon–14, according to the following nuclear equation, is the basis for radiocarbon dating.

$$^{14}_{6}\mathrm{C} \rightarrow {}^{Y}\mathrm{X} + {}^{0}_{-1}\mathrm{e}$$

Identify the element represented by **X** and state the value of **Y**, the mass number of the daughter nucleus.

Explain clearly where the electron lost by the carbon atom in this process comes from. (12)

6. Ethanol and hydrogen are both examples of fuels. Bioethanol is ethanol produced from the fermentation of sugars from plant material by yeast.

(*a*) Define *heat of combustion* of a substance.

What apparatus is used to *accurately* measure the heat of combustion of a fuel? (8)

(*b*) Give one use made of the kilogram calorific values of various fuels. (3)

(*c*) Carbon dioxide and water are produced by the burning of the liquid fuel, ethanol. The combustion of ethanol is described by the following equation.

$$\mathbf{C_2H_5OH}\,(l) + \mathbf{3O_2}\,(g) \rightarrow \mathbf{2CO_2}\,(g) + \mathbf{3H_2O}\,(l)$$

Calculate the heat of combustion of ethanol, given that the heats of formation of carbon dioxide, water and ethanol are –394, –286, and –276 kJ mol^{-1} respectively. (12)

Draw a clearly labelled reaction profile diagram for this reaction.

Suggest one advantage of using bioethanol as a motor fuel. (12)

(*d*) Describe, with the aid of a balanced equation, how hydrogen is produced on a large scale from natural gas (methane).

Give two advantages of using hydrogen as a fuel. (15)

7. (*a*) State *Le Châtelier's principle*. (5)

Ammonia is manufactured by the following reaction in the Haber process making use of a certain catalyst.

$$N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)} \qquad \Delta H = -92 \text{ kJ}$$

(*b*) Explain how Le Châtelier's principle may be used to determine the optimum conditions of temperature and pressure to maximise the yield of ammonia. (9)

(*c*) Why are these conditions *not* used in industry in the preparation of ammonia? (6)

(*d*) Write the equilibrium constant expression (K_c) for the reaction. (6)

(*e*) In an experiment, a mixture of 16.8 g of nitrogen and 1.4 g of hydrogen were placed in a 1 litre flask and allowed come to equilibrium at a certain temperature. When equilibrium was reached, it was found that 6.8 g of ammonia had been produced.

Calculate the value of K_c. (12)

(*f*) What effect, if any, does each of the following have on the value of K_c for this reaction:

(*i*) an increase in the equilibrium temperature,

(*ii*) the use of a more efficient catalyst?

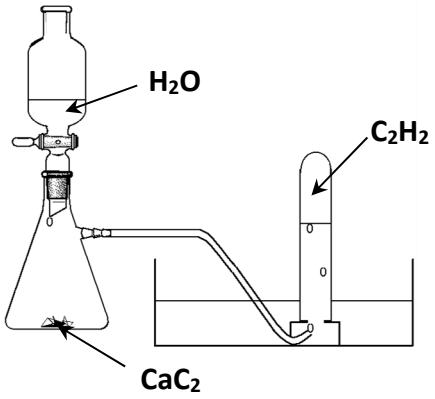
Justify your answer in each case. (12)

8. (*a*) Alkenes and alkynes are described as unsaturated hydrocarbons.

Explain the meaning of the underlined term. (5)

(*b*) Explain, with the aid of diagrams, the difference in structure between an alkene and an alkyne. (6)

(*c*) Ethyne can be produced in the laboratory using the apparatus shown in the diagram.



(*i*) Write a balanced equation for the reaction involved in the laboratory preparation of ethyne.

(*ii*) Describe a test you could carry out to show that ethyne is an unsaturated compound.

(*iii*) Give one large-scale use of ethyne. (15)

(*d*) Classify each of the following conversions as an *addition*, an *elimination* or a *substitution* reaction:

(*i*) ethanol to ethene,

(*ii*) ethane to bromoethane,

(*iii*) ethene to ethane. (9)

(*e*) Describe the reaction mechanism for the monochlorination of methane.

Give one piece of experimental evidence that supports this mechanism. (15)

9. (*a*) In order to determine the total hardness in a water sample, 50.0 cm^3 portions of the water were titrated with a 0.010 M **edta** solution.

The average titre was found to be 15.4 cm^3.

The reaction between the **edta** (represented by $\mathbf{H_2Y^{2-}}$) and the calcium and magnesium ions (both represented by $\mathbf{M^{2+}}$) that are dissolved in the water is given in the following balanced equation:

$$\mathbf{H_2Y^{2-} + M^{2+} \rightarrow MY^{2-} + 2H^+}$$

(*i*) What do the letters **edta** stand for? (5)

(*ii*) What substances must be added to a 50.0 cm^3 water sample before commencing each titration?

Explain the purpose of each of these additions. (12)

(*iii*) Calculate the total hardness of the water sample in p.p.m. in terms of $\mathbf{CaCO_3}$. (12)

(*iv*) Suggest how this titration experiment could be adapted to determine the amount of temporary hardness in the water sample. (9)

(*b*) The diagram shows an ion exchanger that makes use of a replaceable filter cartridge of deionising resins to make deionised water for a school laboratory.

Explain how ion exchange resins can be used to produce deionised water. (12)

10. Answer any **two** of the parts (*a*), (*b*) and (*c*). (2 × 25)

(*a*) What are the steps involved in organic chemical synthesis?

Describe, using structural formulae, a three-step reaction scheme in which ethene (**C_2H_4**) is converted to ethyl ethanoate (**$CH_3COOC_2H_5$**).

Identify, where appropriate, the reagents required for each step. (25)

(*b*) Mass spectrometry can be used to determine the isotopic abundance of a particular element.

State one other application of mass spectrometry.

Analysis of a sample of chromium using a mass spectrometer gave the following results:

Isotope	**^{50}Cr**	**^{52}Cr**	**^{53}Cr**	**^{54}Cr**
Natural abundance	4.345%	83.789%	9.501%	2.365%

Calculate the relative atomic mass (A_r) of chromium, correct to one decimal place, using this data.

What are the fundamental processes, in the sequence in which they occur, involved in the operation of a mass spectrometer? (25)

(*c*) What shapes are possible for a molecule of the formula **QX_2**?

Use electron pair repulsion theory to predict *and* explain the shapes of the following molecules:

NH_3 **CCl_4**

Which of these two compounds, **NH_3** or **CCl_4**, would you expect to be the more soluble in water?

Justify your answer. (25)

11. Answer any **two** of the parts (*a*), (*b*), (c) and (*d*). (2 × 25)

(*a*) Define the term *octane number*.

What molecular characteristics are required to create a hydrocarbon fuel with a high octane number?

List three methods commonly used in oil refining to increase the octane number of a fuel. (25)

(*b*) In an experiment 25.0 cm^3 of 0.10 M sulfuric acid were added to 0.20 g of granulated zinc.

The reaction that occurs is described by the following equation.

$$\mathbf{Zn}_{(s)} + \mathbf{H_2SO_4}_{(aq)} \rightarrow \mathbf{ZnSO_4}_{(aq)} + \mathbf{H_2}_{(g)}$$

Determine which is the limiting reactant.

Calculate

(*i*) the mass of $\mathbf{ZnSO_4}$ produced,

(*ii*) the mass of the *unused* reactant. (25)

(*c*) The strength of an acid depends on the extent to which it dissociates in solution.

Write a balanced equation to show the dissociation in water of

(*i*) **HCl**, a strong acid,

(*ii*) **HCN**, a weak acid.

(*iii*) Identify the two species acting as bases in the following equilibrium.

$$\mathbf{HCl}_{(aq)} + \mathbf{HCN}_{(aq)} \rightleftharpoons \mathbf{Cl^-}_{(aq)} + \mathbf{H_2CN^+}_{(aq)}$$

Traffic film remover (TFR) solutions used in some car washes are very corrosive.

(*iv*) Calculate the pH of a TFR solution that has an $\mathbf{OH^-}$ ion concentration of 0.04 M.

Many alloy wheel cleaning solutions contain acids and are also very corrosive.

(*v*) Calculate the concentration of $\mathbf{H_3O^+}$ ion in an alloy wheel cleaning solution that has a pH of 1.20. (25)

This question continues on the next page.

(*d*) Answer part **A** *or* part **B**.

A

Oxides of nitrogen and of sulfur are associated with environmental issues negatively affecting the Earth's atmosphere.

(*i*) Identify two of these issues.

(*ii*) Give the chemical formulae for two oxides, one oxide of nitrogen and one oxide of sulfur, that are major contributors to the issues that you have mentioned.

(*iii*) Describe how each of these oxides enters the atmosphere.

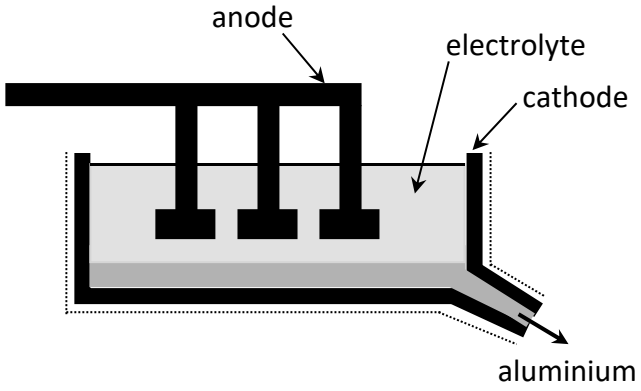
(*iv*) Identify a measure that has been taken to reduce the release of one of these oxides into the atmosphere. (25)

or

B

Although aluminium is placed before (above) iron in the electrochemical series, an object made from aluminium will corrode much more slowly than an object made from iron if both are exposed to air and water.

Why is this the case?



Alumina (**Al_2O_3**) is exported from Ireland to be processed into pure aluminium by the electrolysis of the molten oxide in a cell similar to that shown in the diagram above.

(*i*) Name a suitable material for the anode and the cathode.

(*ii*) Write equations for the reactions that take place at the anode *and* at the cathode.

(*iii*) Describe one feature of the process that reduces the cost of producing aluminium. (25)

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Leaving Certificate – Higher Level

Chemistry

3 Hours Duration