Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2012

CHEMISTRY – HIGHER LEVEL

TUESDAY, 19 JUNE – AFTERNOON 2.00 to 5.00

400 MARKS

Answer **eight** questions in all

These **must** include at least **two** questions from **Section A**

All questions carry equal marks (50)

The information below should be used in your calculations.

Relative atomic masses: H = 1, C = 12, O = 16, Na = 23, Al = 27, S = 32, Cl = 35.5, Ag = 108

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

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

Molar volume at room temperature and pressure = 24.0 litres

The use of the formulae and tables booklet approved for use in the State Examinations is permitted. A copy may be obtained from the examination superintendent.

Section A

Answer at least two questions from this section [see page 1 for full instructions].

1. A student determined the concentration of a hydrochloric acid solution by titration with 25.0 cm^3 portions of a 0.05 M primary standard solution of anhydrous sodium carbonate. The portions of sodium carbonate solution were measured into a conical flask using a 25 cm^3 pipette. The hydrochloric acid solution was added from a burette. The mean titre was 20.8 cm^3.

The balanced equation for the titration reaction was:

$$\mathbf{2HCl + Na_2CO_3 \longrightarrow 2NaCl + H_2O + CO_2}$$

(*a*) Explain the underlined term. (5)

(*b*) Describe how the student should have prepared 500 cm^3 of the 0.05 M primary standard solution from a known mass of pure anhydrous sodium carbonate, supplied on a clock glass. (12)

Calculate the exact mass of anhydrous sodium carbonate (**Na_2CO_3**) required to prepare this solution. (6)

(*c*) (*i*) Describe how the liquid level in the burette was adjusted to the zero mark.

(*ii*) Why was a pipette filler used to fill the pipette with 25.0 cm^3 of the sodium carbonate solution? (6)

(*d*) Name a suitable indicator for this titration.
State the colour change observed at the end point. (9)

(*e*) Calculate, correct to two decimal places, the concentration of the hydrochloric acid solution in

(*i*) moles per litre,

(*ii*) grams per litre. (12)

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2. Ethene gas can be prepared from ethanol in a school laboratory.

(*a*) Draw a labelled diagram showing the arrangement of apparatus and the reagents used in the preparation and collection of the ethene. (11)

(*b*) It is important to be aware of the possibility of a 'suck-back' occurring when carrying out this procedure.

(*i*) At what stage in the procedure is a 'suck-back' most likely to occur?

(*ii*) Give one possible consequence of a 'suck-back' occurring.

(*iii*) How could a 'suck-back' be avoided? (9)

(*c*) Describe how you could test the gas produced for unsaturation. (9)

(*d*) Write a balanced equation for the preparation of ethene from ethanol. (6)

(*e*) When ethanol is converted to ethene by this method, a 60% yield can be expected.

Assuming this percentage yield, what is the maximum number of 75 cm^3 test tubes of ethene gas that could be collected at room temperature and pressure when 2.4 cm^3 of ethanol, density 0.8 g cm^{-3}, react? (15)

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3. The relative molecular mass of a volatile liquid can be found by means of a procedure involving the use of either apparatus **A** or apparatus **B** shown below.

(*a*) Give an example of a liquid suitable for use in this experiment. (5)

(*b*) Describe how (*i*) the mass, (*ii*) the volume, of the vapour is determined. (15)

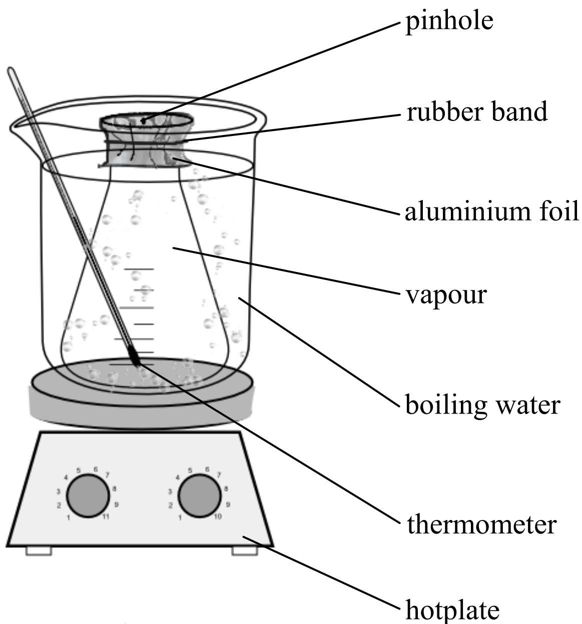
(*c*) Explain why the pressure of the vapour is the same as atmospheric pressure. (6)

(*d*) The vapour of 0.63 g of a pure liquid occupies a volume of 330 cm^3 at a temperature of 100 °C and at a pressure of 101 kPa.

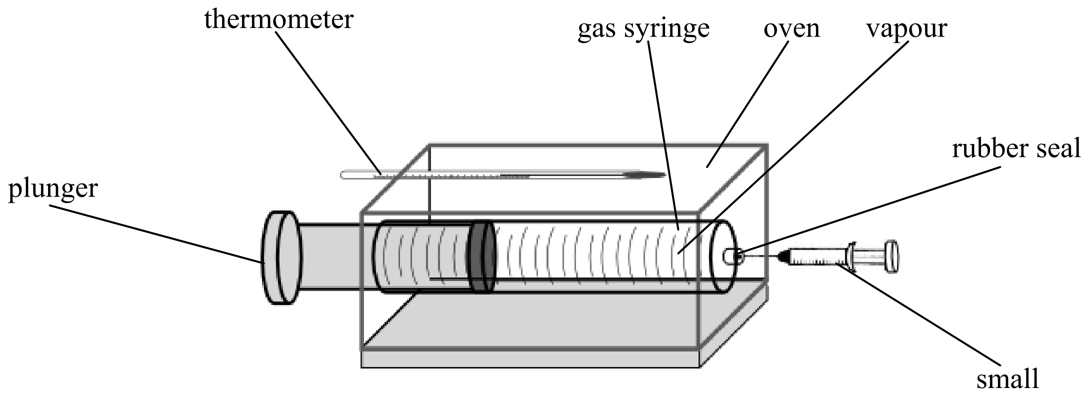
Calculate the number of moles of vapour and hence calculate the relative molecular mass of the volatile liquid. (15)

(*e*) Why is this method unsuitable for liquids that are non-volatile?

What modern instrumental technique could be used as a more accurate method to measure the relative molecular masses of volatile and non-volatile liquids as well as of solid and gaseous substances? (9)



Apparatus **A**



Apparatus **B**

Section B

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

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

(*a*) State the number of (*i*) sub-levels (subshells), (*ii*) orbitals, occupied by electrons in an argon atom in its ground state.

(*b*) Write a balanced nuclear reaction for the beta particle decay of iodine-131.
[See formulae and tables booklet, page 79.]

(*c*) Define *relative atomic mass*.

(*d*) Distinguish between sigma (σ) and pi (π) covalent bonding.

(*e*) Using oxidation numbers, or otherwise, balance the following equation.

$$\mathbf{Cu + NO_3^- + H^+ \longrightarrow Cu^{2+} + NO_2 + H_2O}$$

(*f*) State *Avogadro's law*.

(*g*) Why does raising the temperature generally increase the rates of chemical reactions?

(*h*) Name (*i*) the gas, (*ii*) the ion, formed at the negative electrode when aqueous sodium sulfate solution is electrolysed.

(*i*) Define *bond energy*.

(*j*) What happens during the secondary treatment of sewage?

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

A What is the *structural* difference between low density poly(ethene) and high density poly(ethene)?

or

B What happens in the *scrubbing* of waste acidic gases in industry?

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5. (*a*) Write the electron configuration (*s*, *p*) of an oxygen atom showing the arrangement of electrons in atomic orbitals. (5)

(*b*) Define *atomic radius* (*covalent radius*).

State and explain the trend in atomic radii (covalent radii) across the second period of the periodic table of the elements. (12)

(*c*) Give **one** reason why electronegativity values exhibit a general increase across the second period of the periodic table. (3)

(*d*) Consider the following hydrides of some of the elements from the second and third periods of the periodic table: $\mathbf{H_2O}$ $\mathbf{NH_3}$ $\mathbf{PH_3}$ **HCl**

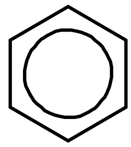
(*i*) State how the bonding in $\mathbf{PH_3}$ differs from the bonding in the other three hydrides.
What is the reason for this difference in bonding?

(*ii*) From these four hydrides, identify the hydride or hydrides in which hydrogen bonding occurs between the molecules.
Give **one** property that is affected by the presence of intermolecular hydrogen bonding in the hydride or hydrides you have identified.

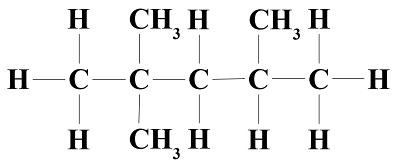
(*iii*) State the shape of the $\mathbf{PH_3}$ molecule and explain using electron-pair repulsion theory how this shape arises. (21)

(*e*) Boron trichloride ($\mathbf{BCl_3}$) is a colourless gas. Would you expect (*i*) the **B–Cl** bonds, (*ii*) the $\mathbf{BCl_3}$ molecules, to be polar or non-polar? Justify your answers. (9)

6. (*a*) Several processes are used in oil refining to convert less useful hydrocarbons into more useful ones. For each conversion, (*i*) to (*iii*), name the process involved. (8)

(*i*) $C_6H_{14\,(l)} \rightarrow 4H_{2\,(g)}$ +  (l)

(*ii*) $C_{14}H_{30\,(l)} \rightarrow C_7H_{16\,(l)} + C_3H_{6\,(g)} + \underline{X}_{(g)}$

(*iii*) $CH_3(CH_2)_6CH_{3\,(l)} \rightarrow$  (l)

(*b*) Name a hydrocarbon that **X** could be and draw its structural formula.

Name the product of process (*iii*) and state its octane number. (12)

(*c*) Explain why the substance MTBE (methyl *tert*-butyl ether) is sometimes added to motor fuel.

Name the substance previously added to motor fuel for the same purpose and state why its use was discontinued. (9)

(*d*) Define *heat of combustion*.

Name the laboratory apparatus used to measure the heats of combustion of fuels and foodstuffs. (9)

(*e*) Calculate the heat of formation of the hydrocarbon (C_8H_{18}) produced in process (*iii*), given that its heat of combustion value has been measured to be –5502 kJ mol^{-1} and that the heats of formation of carbon dioxide and water are –394 and –286 kJ mol^{-1}, respectively. (12)

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7. (*a*) Explain how hard water is caused and how it wastes soap. How can hard water be softened by ion exchange so that it is suitable for use as deionised water in the laboratory? (11)

(*b*) In water treatment, what is the purpose of adding each of the following: (*i*) a flocculating agent, (*ii*) chlorine, (*iii*) a fluorine-containing compound, (*iv*) calcium hydroxide, (*v*) sulfuric acid? (15)

State the problem that would arise when each of any **two** of these substances is added in excessive quantity. (6)

(*c*) Why is water pollution by heavy metal ions, e.g. Hg^{2+} or Pb^{2+}, a cause of concern?

Name an instrumental technique that could be used to detect and measure the concentration of a heavy metal ion in a water sample.

Explain how Hg^{2+} or Pb^{2+} ions can be removed from a water supply. (12)

(*d*) Describe a test for the presence of chloride ion (Cl^-) in water. (6)

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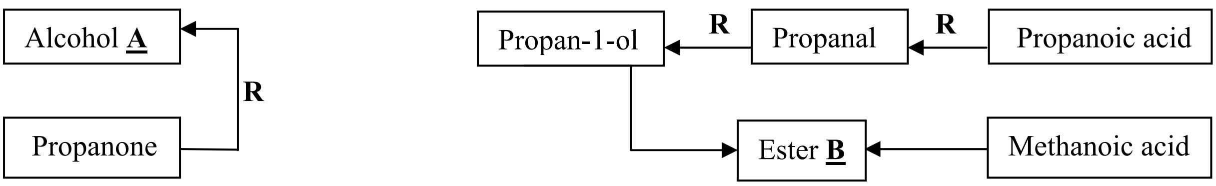
8. Study the reaction scheme and answer the questions that follow.



(*a*) Give the systematic (IUPAC) name for (*i*) the alcohol **A**, (*ii*) the ester **B**. (8)

(*b*) Alcohol **A** and propan-1-ol are structural isomers. Explain the underlined term.

What is the structural difference between a primary alcohol and a secondary alcohol?

Identify another pair of structural isomers from the reaction scheme. (18)

(*c*) Identify a compound in the scheme whose carbon atoms are all in tetrahedral geometry. (3)

(*d*) Name the reagent and catalyst used to bring about the conversions labelled **R**. (6)

(*e*) Propanal is oxidised by Fehling's reagent. Describe how this reaction is carried out.

Why does propanone not react with Fehling's reagent? (12)

(*f*) Which compound in the scheme would you expect to have a fruity odour? (3)

9. (*a*) Define *rate of reaction*. (5)

The loss of mass of a mixture of 50 cm^3 of a 2 M solution of hydrochloric acid and excess marble chips was monitored over time and the following data were recorded.

Loss of mass / g	0.00	0.10	0.18	0.29	0.35	0.39	0.41	0.41
Time / s	0	20	40	80	120	160	220	240

Plot a graph to show the mass of carbon dioxide produced (loss of mass) *versus* time. (12)

Use your graph to find the instantaneous rate of the reaction at 60 seconds in terms of g/s carbon dioxide produced. (6)

Mark clearly on your graph the curve you would expect to obtain if the reaction were repeated using 50 cm^3 of a 1 M solution of hydrochloric acid. Justify the shape and position of this curve relative to the graph you have plotted. (9)

(*b*) When hydrogen peroxide is added to a warm solution of potassium sodium tartrate, a slow reaction occurs in which tartrate ions are oxidised to carbon dioxide and water. If cobalt(II) ions ($\mathbf{Co^{2+}}$) are added as a catalyst, a big increase in the reaction rate is observed.

What type of catalysis is involved in this reaction? (3)

What colour changes are observed when $\mathbf{Co^{2+}}$ ions catalyse the reaction? (6)

Explain the significance of the colour changes. (9)

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

(*a*) In general, alkenes are more reactive than alkanes. Alkenes undergo addition reactions and alkanes undergo substitution reactions.

(*i*) Account for the greater reactivity of alkenes compared to alkanes. (7)

(*ii*) Describe the mechanism of the addition of bromine ($\mathbf{Br_2}$) to ethene.

State one piece of evidence to support the mechanism you have described. (18)

(*b*) Define *an acid* in terms of the Brønsted-Lowry theory.

What is a *conjugate pair*? (7)

A certain water soluble acid-base indicator represented by **HIn** is a weak acid which dissociates as follows in water.

$$\underset{\text{green}}{\mathbf{HIn}} \quad \leftrightharpoons \quad \mathbf{H^+} \; + \; \underset{\text{purple}}{\mathbf{In^-}}$$

State and explain the colour observed when a few drops of a solution of the indicator are added to a 0.5 M **NaOH** solution. (6)

Calculate the pH of (*i*) the 0.5 M **NaOH** solution, (*ii*) a 0.1 M solution of the indicator, given that its K_a value is 2.0×10^{-5}. (12)

(*c*) A bracelet, originally made of pure silver, became tarnished over time with black silver sulfide ($\mathbf{Ag_2S}$) forming on the surface. The bracelet was cleaned by converting the silver sulfide back to metallic silver using aluminium in the following reaction. The mass of the bracelet decreased by 0.0096 g in the cleaning process.

$$\mathbf{3Ag_2S \; + \; 2Al \; \longrightarrow \; 6Ag \; + \; Al_2S_3}$$

(*i*) What substance was oxidised in this cleaning process? (4)

(*ii*) How many moles of sulfur (**S**) were removed from the bracelet when the silver sulfide ($\mathbf{Ag_2S}$) was converted to aluminium sulphide ($\mathbf{Al_2S_3}$)? (6)

(*iii*) What mass of aluminium was used in the reaction? (9)

(*iv*) What would the loss in mass of the tarnished bracelet have been if it had been cleaned by the alternative method of removing all of the silver sulfide by polishing? (6)

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

(*a*) In 1909 Rutherford bombarded a very thin sheet of gold foil with alpha particles, most of which passed straight through it undeflected. Some alpha particles, however, were deflected at large angles and a very small number were reflected back along their original paths. The first of these observations was not inconsistent with the 'plum pudding' model of the atom that had been proposed by Thomson in 1904, but Rutherford had to formulate a new model of atomic structure to account for the other two observations.

(*i*) What are alpha particles? (4)

(*ii*) Describe the structure of Thomson's 'plum pudding' model of the atom. (6)

(*iii*) Explain why some alpha particles were deflected at large angles as they passed through the gold foil. (6)

(*iv*) Why were some alpha particles reflected back along their original paths?
Why did this happen to only a very small number of alpha particles? (6)

(*v*) Draw a labelled diagram to show the new structure of the atom proposed by Rutherford. (3)

(*b*) Consider the following room temperature equilibrium reaction used to dissolve iodine (**I_2**) crystals in an aqueous solution of iodide ions (**I^-**).

$$I_{2\,(aq)} + I^-_{(aq)} \rightleftharpoons I^-_{3\,(aq)}$$

When 0.0800 moles of iodine crystals and 0.2400 moles of iodide ions were added to deionised water and made up to a litre of solution, 0.0793 moles of triiodide ions (**I_3^-**) were present at equilibrium.

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

Calculate the value of the equilibrium constant (***K_c***) for the reaction at room temperature. (12)

State and explain the effect on the equilibrium concentration of triiodide ions of adding a substance that reacts with iodine, e.g. starch. (7)

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

A

Bauxite from Africa is transported to Aughinish in Co. Limerick, where it is converted to pure alumina (**Al_2O_3**). The alumina is then shipped to Russia where aluminium metal is produced from it by electrolysis.

(*i*) Describe the chemical processes used to produce pure alumina from bauxite. (12)

(*ii*) Draw a labelled diagram of the electrolytic cell used to produce aluminium metal from alumina. (9)

(*iii*) Explain why the recycling of aluminium is environmentally desirable. (4)

or

B

(*i*) Give one major commercial use for nitrogen gas. (4)

(*ii*) Explain why nitrogen gas is chemically inert. (6)

(*iii*) What is meant by the *fixation* of nitrogen gas in the atmosphere? (6)

(*iv*) Describe how atmospheric nitrogen gas is fixed by lightning. (9)

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