Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2008

CHEMISTRY – HIGHER LEVEL

THURSDAY, 5 JUNE – AFTERNOON 2.00 to 5.00

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400 MARKS

Answer **eight** questions in all

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

All questions carry equal marks (50)

Information

Relative atomic masses: H = 1, C = 12, O = 16

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

Molar volume at room temperature and pressure = 24.0 litres

Avogadro constant = $6 \times 10^{23}\ \text{mol}^{-1}$

Section A

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

1. To determine the concentration of ethanoic acid, **CH_3COOH**, in a sample of vinegar, the vinegar was first diluted and then titrated against 25.0 cm^3 portions of a previously standardised 0.10 M solution of sodium hydroxide, **NaOH**. One rough and two accurate titrations were carried out.

The three titration figures recorded were 22.9, 22.6 and 22.7 cm^3, respectively.

(*a*) Why was the vinegar diluted? (5)

(*b*) Describe the correct procedures for measuring exactly 25.0 cm^3 of vinegar and diluting it to exactly 250 cm^3 using deionised water. (15)

(*c*) The equation for the titration reaction is:

$$\mathbf{CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O}$$

Name an indicator suitable for this titration. Justify your choice of indicator.
State the colour change at the end point. (12)

(*d*) Calculate the concentration of the diluted solution of ethanoic acid in

(*i*) moles per litre, (*ii*) grams per litre.

State the concentration of ethanoic acid in the original vinegar sample in grams per litre.

Express this concentration in terms of % (w/v). (15)

(*e*) Ethanoic acid is a carboxylic acid. Identify the carboxylic acid which occurs in nettles and stinging ants. (3)

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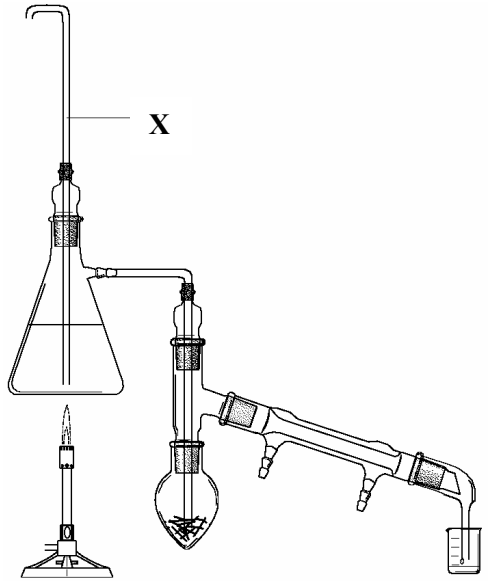
2. Chromatography is widely used in chemistry as a separation technique.

(*a*) Describe, with the aid of clearly labelled diagrams, how you would set up and carry out an experiment to separate the components in a mixture of indicators using paper chromatography, thin-layer chromatography or column chromatography. (15)

(*b*) Explain why the different components of the mixture travel different distances along the paper or along the thin-layer or through the column in a given time. (6)

Steam distillation, using an apparatus like that shown, is a technique used to isolate an organic substance from plant material. The principle of this technique is that the boiling point of a mixture of two *immiscible liquids* is below the boiling points of both pure liquids. This allows the organic substance to be isolated at temperatures below 100 ºC and avoids the delicate organic molecules being damaged at high temperatures.



(*c*) What is meant by the term *immiscible liquids*? (3)

(*d*) Name a substance you isolated by steam distillation in the school laboratory and the plant material from which it was extracted. (6)

(*e*) Explain the function of the tube labelled **X**. (6)

(*f*) Describe the appearance of the distillate collected. Name or describe briefly a technique that could be used to separate the organic substance from the water. (9)

(*g*) In a steam distillation experiment 20.0 g of plant material were heated in the presence of steam. Only 0.250 g of pure organic liquid was obtained. Calculate the percentage yield. (5)

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3. (*a*) Hydrogen peroxide solution is an oxidising reagent. Draw *or* describe the warning symbol put on a container of hydrogen peroxide solution to indicate this hazard. (5)

(*b*) Write a balanced equation for the decomposition of hydrogen peroxide. (6)

(*c*) Solid manganese(IV) oxide catalyst was added to a hydrogen peroxide solution at a time known exactly and the rate of production of gas was monitored as the hydrogen peroxide decomposed. Draw a labelled diagram of an apparatus that could be used to carry out this experiment. (12)

(*d*) The table shows the volumes of gas (at room temperature and pressure) produced at intervals over 12 minutes.

Time / minutes	0.0	1.0	2.0	3.0	5.0	7.0	9.0	11.0	12.0
Volume / cm^3	0.0	20.0	36.0	50.5	65.5	73.0	76.5	78.0	78.0

Plot a graph of the volume of gas produced *versus* time.

Explain why the graph is steepest at the beginning. (15)

(*e*) Use your graph to

(*i*) determine the instantaneous rate of gas production at 5 minutes,

(*ii*) calculate the total mass of gas produced in this experiment. (12)

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*) Write the electron configuration (*s, p, etc.*) of the aluminium ion (Al^{3+}).

(*b*) What contribution did Henry Moseley, the scientist shown in the photograph, make to the systematic arrangement of the elements in the periodic table?

(*c*) Give **two** properties of alpha particles.

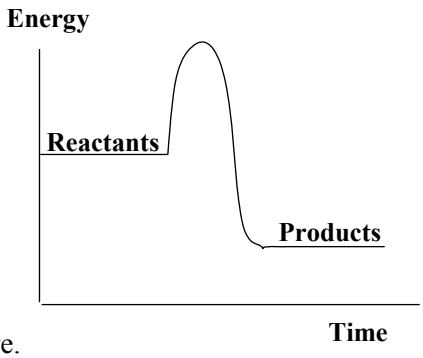
(*d*) Name the type of spectroscopy, based on absorptions within a particular range of electromagnetic frequencies, and used as a 'fingerprinting' technique to identify organic and inorganic compounds.

(*e*) Write the formula of (*i*) a substance which causes temporary hardness in water, (*ii*) a substance which causes permanent hardness in water.

(*f*) Name **two** metals which act as catalysts in the catalytic converters of modern cars.

(*g*) Account for the difference in bond angle between water (104.5 º) and methane (109.5 º).

(*h*) Copy the diagram of an exothermic reaction profile into your answer book and mark clearly (*i*) the activation energy, (*ii*) ΔH for the reaction.



(*i*) What is the purpose of tertiary treatment of sewage?

(*j*) Complete and balance the equation:

$$C_2H_5OH + Na \longrightarrow$$

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

A State the **two** main ways by which nitrogen is fixed in nature.

or

B State **two** ways in which steel differs from the iron produced in a blast furnace.

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5. (*a*) Define *electronegativity*. (5)

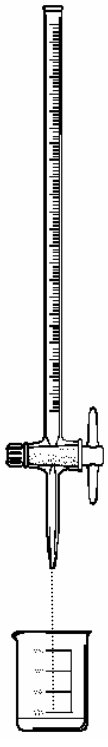
(*b*) State and explain the trend in electronegativity values down the first group in the periodic table of the elements. (9)

(*c*) Use electronegativity values to predict the types of bonding (*i*) in water, (*ii*) in methane, (*iii*) in magnesium chloride. (9)

(*d*) Use dot and cross diagrams to show the formation of bonds in magnesium chloride. (6)

(*e*) Explain the term *intermolecular forces*. (6)

(*f*) Use your knowledge of intermolecular forces to explain why methane has a very low boiling point (b.p. = –164 ºC).
The relative molecular mass of methane is only slightly lower than that of water but the boiling point of water is much higher (b.p. = 100 ºC). Suggest a reason for this. (6)



(*g*) The diagram shows a thin stream of liquid flowing from a burette. A stream of water is deflected towards a positively charged rod whereas a stream of cyclohexane is undeflected. Account for these observations
Explain what would happen in the case of the stream of water if the positively charged rod were replaced by a negatively charged rod. (9)

6. (*a*) The hydrocarbon molecules in petrol typically contain carbon chains with between five and ten carbon atoms. The most widely used petrol in Ireland has an octane number of 95.

(*i*) What is meant by the *octane number* of a fuel? (5)

(*ii*) The two hydrocarbons used as references when establishing the octane number of a fuel are heptane and 2,2,4-trimethylpentane. Draw the structure of each of these molecules. (6)

(*iii*) Crude oil is separated into a number of fractions in oil refining. Name the **two** fractions which contain molecules with the carbon chain lengths needed for petrol. (6)

(*iv*) Dehydrocyclisation is one of the processes used to increase the octane numbers of hydrocarbons. What **two** changes to the hydrocarbon molecules occur during this process? (6)

(*v*) Ethanol is an example of an oxygenate. Give another example of an oxygenate. Give **two** reasons why oxygenates are added to petrol. (9)

(*b*) Write a balanced chemical equation for the combustion of ethanol, $\mathbf{C_2H_5OH}$. Given that the heats of formation of ethanol, carbon dioxide and water are –278, –394 and –286 kJ mol^{-1}, respectively, calculate the heat of combustion of ethanol. (18)

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7. A chemical equilibrium is established when eleven moles of hydrogen and eleven moles of iodine are mixed at a temperature of 764 K. Initially the colour of the mixture is deep purple due to the high concentration of iodine vapour. The purple colour fades and when equilibrium is established the colour of the mixture is pale pink and there are seventeen moles of hydrogen iodide present.

The equilibrium is represented by the equation

$$\underset{\text{colourless}}{\mathbf{H_{2\,(g)}}} + \underset{\text{purple}}{\mathbf{I_{2\,(g)}}} \rightleftharpoons \underset{\text{colourless}}{\mathbf{2HI_{(g)}}} \qquad \mathbf{\Delta H = 51.8\ kJ}$$

(*a*) What is meant by *chemical equilibrium*?
When the colour of the mixture has become pale pink, has reaction ceased? Explain. (11)

(*b*) Write an expression for the equilibrium constant ($\boldsymbol{K_c}$) for the reaction. (6)
Calculate the value of the equilibrium constant ($\boldsymbol{K_c}$) at 764 K. (12)

(*c*) State *Le Châtelier's principle*. (6)

Use Le Châtelier's principle to predict and explain the effect of a decrease in temperature on
(*i*) the yield of hydrogen iodide, (*ii*) the intensity of colour of the equilibrium mixture. (9)

What change, if any, will an increase in the pressure on the equilibrium mixture have on the yield of hydrogen iodide? Explain. (6)

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8. (*a*) (*i*) Write an expression for the self-ionisation of water. (5)

(*ii*) Define $\boldsymbol{K_w}$, the ionic product of water.
The value of $\boldsymbol{K_w}$ at 25 ºC is 1.0×10^{-14}. Show that the pH of pure water is 7.0 at 25 ºC. (12)

(*iii*) Calculate the pH of a 0.5 M solution of a strong monobasic (monoprotic) acid.
Calculate the pH of a 0.5 M solution of a weak monobasic acid with a $\boldsymbol{K_a}$ value of 1.8×10^{-5}. (12)

(*b*) (*i*) Explain clearly how suspended solids are removed in the treatment of water for drinking. (9)

(*ii*) Identify **two** chemicals added at the final stages of the treatment of water for drinking. State the purpose of adding each chemical you have identified. (12)

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9. The alkenes are a homologous series of *unsaturated* hydrocarbons. Ethene (C_2H_4) is the first member of the series. Alkenes undergo addition reactions and polymerisation reactions.

(*a*) Draw a labelled diagram of an apparatus used to prepare ethene gas in the school laboratory. (8)

(*b*) Draw the structure of any one of the isomers of the third member of the alkene series. Indicate clearly which carbon atoms have planar bonding and which are bonded tetrahedrally. (12)

(*c*) Explain the term *unsaturated*. (6)

(*d*) The ionic addition mechanism for the reaction of ethene with bromine water involves the formation of an intermediate ionic species. Draw the structure of this species.

Give the names or structural formulas of the three products that would be formed if the bromine water used in the reaction contained sodium chloride.

How does the formation of these three products support the mechanism of ionic addition? (18)

(*e*) Name the polymer formed when ethene undergoes addition polymerisation.
Draw **two** repeating units of this polymer. (6)

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

(*a*) A student is given a bucket of seawater.

(*i*) Describe how the student could determine by filtration the total suspended solids (expressed as ppm) in the water. (9)

(*ii*) How could the student determine the total dissolved solids (expressed as ppm) in a sample of the filtered seawater? (9)

(*iii*) Describe a test to confirm the presence of the chloride ion in aqueous solution. (7)

(*b*) Define oxidation in terms of (*i*) electron transfer, (*ii*) change in oxidation number. (7)

(*iii*) For the redox reactions shown below, use oxidation numbers to identify the species oxidised in the first reaction and the oxidising reagent in the second reaction. (6)

$$ClO^- + I^- + H^+ \longrightarrow Cl^- + I_2 + H_2O$$

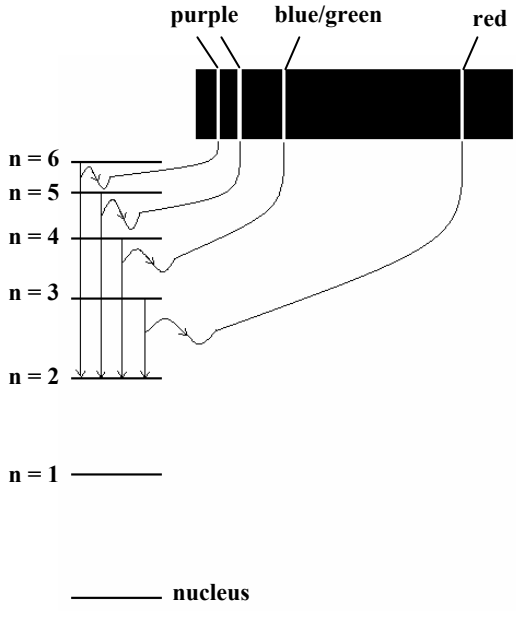
$$I_2 + S_2O_3^{2-} \longrightarrow I^- + S_4O_6^{2-}$$

(*iv*) Using oxidation numbers or otherwise balance both equations. (12)

(*c*) (*i*) Define *energy level*. (4)

(*ii*) Distinguish between *ground state* and *excited state* for the electron in a hydrogen atom. (6)

The diagram shows how Bohr related the lines in the hydrogen emission spectrum to the existence of atomic energy levels.



(*iii*) Name the series of lines in the visible part of the line emission spectrum of hydrogen. (3)

(*iv*) Explain how the expression $E_2 - E_1 = hf$ links the occurrence of the visible lines in the hydrogen spectrum to energy levels in a hydrogen atom. (12)

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

(*a*) Alcohols can be obtained by the reduction of aldehydes and ketones using hydrogen and a suitable catalyst.

(*i*) Name a suitable catalyst for these reduction reactions. (4)

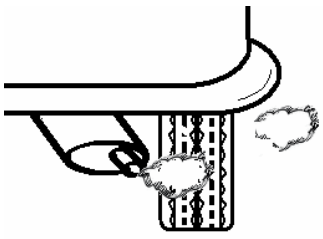
(*ii*) Name the alcohol produced when propanal (**C_2H_5CHO**) is reduced. (3)

(*iii*) Draw the structure of the alcohol produced when propanone (**CH_3COCH_3**) is reduced. To which class (primary, secondary or tertiary) of alcohols does it belong? (6)

(*iv*) Which of the two compounds, propanal or propanone, would be oxidised by warm Fehling's solution? Give the name *and* structure of the organic product of the oxidation reaction. (9)

(*v*) Give **one** common use for propanone. (3)

(*b*) From July 2008 changes will apply to the way in which taxes are levied on new cars bought in Ireland. Vehicles that, in controlled tests, have higher levels of carbon dioxide emission per kilometre travelled will be subject to higher levels of taxation. The measures are designed to encourage the purchase of cars that are more fuel-efficient and have lower CO_2 emissions.



The manufacturer's specification for a certain diesel-engined car is 143 g CO_2 / km (i.e. the car produces 143 g of CO_2 for every kilometre travelled). The car is used for morning and afternoon school runs totalling 8 km per day.

Use the manufacturer's CO_2 emission figure to calculate the amount of CO_2 produced each day during the school runs in terms of

(*i*) the mass of CO_2, (*ii*) the number of moles of CO_2,

(*iii*) the volume of CO_2 at room temperature and pressure. (18)

If a large SUV (sports utility vehicle) with a CO_2 emission rating of 264 g CO_2 / km were used instead of the car mentioned above, how many more litres of CO_2 would be released into the atmosphere per day during the school runs? (7)

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

A

Al Gore

In 2007 former US Vice-President Al Gore and the UN Climate Change Committee were awarded the Nobel Peace Prize for their work in highlighting climate change. Al Gore has stressed the need to control global carbon dioxide emissions. Carbon dioxide is a *greenhouse gas* and an *acidic oxide*.

(*i*) Explain the underlined terms. (7)

(*ii*) State **two** major ways by which human activities contribute to the addition of carbon dioxide to the atmosphere. (6)

(*iii*) Carbon dioxide is removed from the atmosphere when it dissolves in rainwater, in seas, in lakes, etc.
What three chemical species form as a result of carbon dioxide gas dissolving in water? (9)

(*iv*) Acidic oxides can be removed from waste gases by scrubbers in chimneys before the gases are released into the atmosphere. Name a reagent used in scrubbers to remove acidic oxides. (3)

or

B

(*i*) Name the ore from which aluminium is extracted. What substance is used to convert this ore into a soluble aluminium compound in the first stage of the extraction? (7)

(*ii*) Write balanced equations for the reactions taking place at the positive and negative electrodes in the electrolysis of alumina. (12)

(*iii*) What is the function of cryolite (**Na_3AlF_6**) in the electrolysis of alumina? (3)

(*iv*) Why is recycling of aluminium metal important for the protection of the environment? (3)

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