



**Coimisiún na Scrúduithe Stáit
State Examinations Commission**

LEAVING CERTIFICATE EXAMINATION, 2010

CHEMISTRY – HIGHER LEVEL

TUESDAY, 22 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)

Information

Relative atomic masses: H = 1, C = 12, O = 16, Na = 23, P = 31, Cl = 35.5, Ca = 40, Fe = 56

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

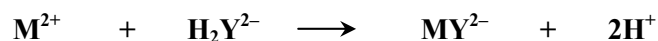
Avogadro constant = $6.0 \times 10^{23} \text{ mol}^{-1}$

Section A

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

1. The total hardness values of a water supply before and after it had been passed through a laboratory deioniser were compared. This was done by adding a suitable indicator and a small volume of buffer solution to 50.0 cm³ samples of the water in a conical flask and titrating with **edta** solution.

The reaction between the calcium ions and the magnesium ions (represented by M²⁺) in the water and the edta (represented by H₂Y²⁻) is given in the following balanced equation.



- (a) What is the full name of the **edta** reagent? (5)
- (b) Name an indicator suitable for this titration and state the colour change observed at the end point of the titration. (9)
- (c) What is the general purpose of buffer solutions?
What buffer was required for this titration?
What problem would have been encountered in this titration if the wrong buffer were used? (9)
- (d) Explain the two operations, involving the titration flask and its contents, carried out as the edta was being added from the burette during the titrations. (6)
- (e) It was found that 50.0 cm³ samples of the hard water before ion exchange required an average of 9.20 cm³ of 0.01 M edta solution for complete reaction and that 50.0 cm³ samples of the water after ion exchange required an average of 2.40 cm³ of the same edta solution for complete reaction.

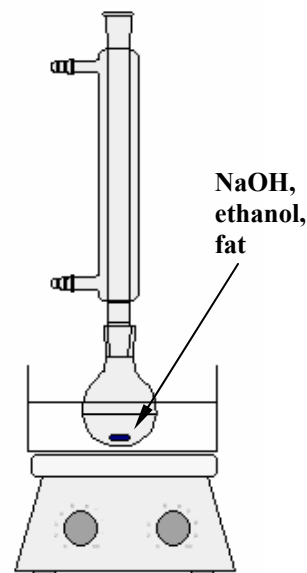
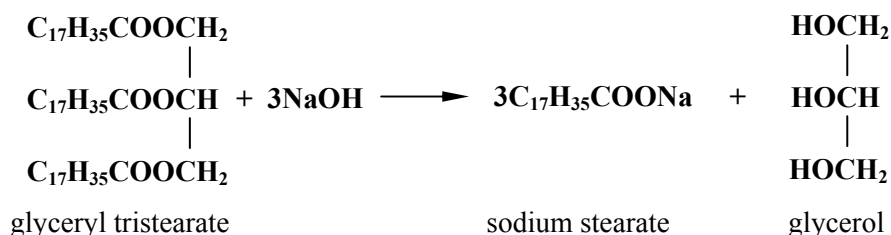
Calculate the total hardness of the water before ion exchange in

- (i) moles per litre of calcium and magnesium ions (M²⁺),
(ii) grams per litre expressed in terms of CaCO₃,
(iii) ppm in terms of CaCO₃.

Repeat these calculations for the water after ion-exchange. (15)

- (f) State and explain whether the water having passed through the deioniser is suitable for use as deionised water in the laboratory or if the deioniser needs to be changed or regenerated. (6)

2. To prepare soap, a student refluxed 8.9 g of glyceryl tristearate (obtained from animal fat), 2 g of sodium hydroxide pellets and 30 cm³ of ethanol, together with a few anti-bumping granules, using the apparatus shown on the right. At the end of the experiment 7.0 g of pure, dry soap were isolated. The balanced equation for the reaction is as follows:



- (a) Write the systematic (IUPAC) name for glycerol. (5)
- (b) Why was the reaction mixture heated under reflux?
Name the type of reaction that occurred during the reflux.
What was the purpose of the ethanol? (12)
- (c) (i) Describe, with the aid of labelled diagrams, how the ethanol was removed after the reflux stage.
(ii) How was the soap isolated from the other substances left in the reaction mixture?
(iii) After isolating the soap, how was it purified and dried? (21)
- (d) Given that the sodium hydroxide was in excess, calculate the percentage yield of soap (sodium stearate). (12)

3. A stopwatch was started when 50 cm³ of a 0.20 M sodium thiosulfate solution was poured into a conical flask containing 10 cm³ of 1.0 M HCl solution. The conical flask was put standing on top of a black cross marked on white paper. The time for the cross to become obscured by the precipitate produced in the reaction was measured. The reciprocal of this reaction time (1/t) was taken as a measure of the initial rate of the chemical reaction.

The stock 0.20 M solution of sodium thiosulfate was then diluted with deionised water to produce 50 cm³ each of 0.16 M, 0.12 M, 0.08 M, 0.04 M and 0.02 M solutions in turn. The times taken for these solutions to react with 10 cm³ of the 1.0 M HCl solution were also measured in identical conical flasks as described above. All six reactions were carried out at 20 °C and the results are given in the table.

Concentration Na₂S₂O₃ (M)	0.20	0.16	0.12	0.08	0.04	0.02
Reaction time (min)	1.14	1.43	1.89	2.94	5.88	11.11
1/t (min⁻¹)	0.88	0.70	0.53	0.34	0.17	0.09

- (a) Identify the precipitate produced in each flask. (5)
- (b) Describe a procedure for diluting the 0.20 M sodium thiosulfate solution to give 50 cm³ of a 0.12 M solution. (9)
- (c) Why are the concentration and the volume of the HCl solution kept constant? (6)
- (d) Plot a graph of reaction rate (1/t) *versus* concentration of sodium thiosulfate.
What conclusion can be drawn from the graph about the relationship between the rate of the reaction and the concentration of the sodium thiosulfate? (18)
- (e) Use your graph to predict the time taken for 50 cm³ of a 0.10 M solution of sodium thiosulfate to react with 10 cm³ of the 1.0 M HCl solution at 20 °C. (6)
- (f) The procedure described above was repeated using 50 cm³ portions of the 0.20 M sodium thiosulfate solution and 10 cm³ portions of the 1.0 M HCl solution at a number of different temperatures between 10 °C and 70 °C and the reaction times were measured as before.
Would you expect the reaction times to increase, decrease, or stay the same, as the temperature was increased? Justify your answer. (6)

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 oxygen (oxide) ion (O^{2-}).
- (b) State **two** differences between Mendeleev's periodic table and the modern periodic table of the elements.
- (c) What are the **two** possible shapes of molecules of general formula QX_2 ?
- (d) How many atoms of iron are there in a 30 g bowl of cornflakes that contains 0.0024 g iron per 30 g serving?
- (e) State *Gay-Lussac's law of combining volumes*.
- (f) Define *activation energy*.
- (g) Distinguish between sigma (σ) and pi (π) covalent bonding.
- (h) What is an *ideal gas*?
- (i) What happens during the secondary stage of sewage treatment?
- (j) Draw the structural formulae of any two molecules with the molecular formula $\text{C}_3\text{H}_6\text{O}_2$.
- (k) Answer part **A** or part **B**.

A Write a balanced equation for the reduction of iron(III) oxide by carbon monoxide in a blast furnace.

or

B Write a balanced equation for the reaction that occurs when sulfur dioxide from industrial gaseous emissions dissolves in water.

5. (a) State **two** assumptions of Dalton's atomic theory of 1808. (8)

(b) The electron was the first of the sub-atomic particles to be discovered. It was identified in experiments using cathode rays that were carried out in the late nineteenth century.

Name the scientist

- (i) who, about 1897, measured the ratio of charge to mass of the electron, e/m ,
- (ii) who, about 1910, proved that the electrons in an atom reside in an electron cloud surrounding a small dense positive central nucleus,
- (iii) who, about 1911, measured the charge on the electron, e . (9)

(c) The arrangement of the electrons in the electron cloud proposed in 1913 by Bohr, pictured on the right, was consistent with the hydrogen emission spectrum.

Outline Bohr's atomic theory based on the hydrogen emission spectrum. (15)

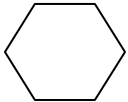
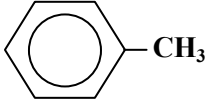
(d) State **two** limitations of Bohr's theory that led to its modification. (6)

(e) Define *atomic orbital*.

Draw the shape of the *p*-orbital.

State the maximum number of electrons that can be accommodated in a *p*-orbital. (12)



6. (a) Give the systematic (IUPAC) names for the three hydrocarbon compounds X, Y and Z. (8) $\text{CH}_3(\text{CH}_2)_5\text{CH}_3$ X
- (b) Compounds X and Z are obtained from the same fraction in the oil refining process. Name the fraction in which X and Z occur. What **two** properties of the compounds are responsible for them being found in the same fraction? (9)  Y
- (c) What is meant by *auto-ignition* in petrol engines? Compound Y has an octane number of 83 and therefore has the same octane rating as an 83:17 mixture of two reference hydrocarbons. Name the reference hydrocarbon that is the major component of the 83:17 reference mixture. (6)  Z
- (d) Define *heat of combustion*. Outline how the heat of combustion of X could be measured using a bomb calorimeter. (15)
- (e) In order to increase its octane rating, compound X is converted to compound Z in oil refineries by the following reforming (dehydrocyclisation) process:



Calculate the heat change for this reaction given that the heats of formation of $\text{C}_7\text{H}_{16}(\text{l})$, and $\text{C}_7\text{H}_8(\text{l})$ are -224.2 and 12.4 kJ mol^{-1} , respectively.

State **one** important industrial use for the hydrogen produced in this reaction. (12)

7. Phosphorus(V) chloride decomposes into phosphorus(III) chloride and chlorine at a temperature of 500 K according to the following balanced equation.



- (a) This is a reversible reaction and a dynamic equilibrium is reached. Explain the underlined terms. Why is the equilibrium described as *dynamic*? (11)
- (b) State *Le Châtelier's principle*. Write the equilibrium constant (K_c) expression for the above reaction. (12)
- (c) When 208.50 g of phosphorus(V) chloride is heated in a 100 litre container at a temperature of 500 K equilibrium is established with 53.25 g of chlorine gas present in the container. Calculate the value of the equilibrium constant (K_c) for the reaction at 500 K. (12)
- (d) When the temperature of the equilibrium mixture is increased, the phosphorus(V) chloride decomposes further. Is the reaction endothermic or exothermic? Justify your answer. (6)
- (e) What change, if any, would an increase in pressure have on the value of K_c ? Explain. (9)

8. (a) Define (i) acid, (ii) conjugate acid, according to the Brønsted-Lowry theory. (8)
- In acting as an acid-base indicator methyl orange behaves like a weak acid. Letting **HX** represent methyl orange, it dissociates as follows:



In aqueous solution, the undissociated form (**HX**) is red and the dissociated form (**X⁻**) is yellow.

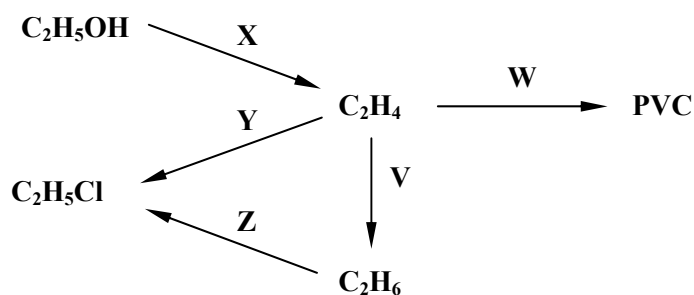
Distinguish between a strong acid and a weak acid. (6)

What is the conjugate base of **HX**? (3)

- (b) State and explain the colour observed when a few drops of the methyl orange solution is added to (i) a 0.1 M solution of **HCl**, (ii) a 0.1 M solution of **NaOH**. (12)
- (c) Calculate the pH of (i) a 0.1M solution of **NaOH**, (ii) a 0.004 M solution of methyl orange, if methyl orange has a K_a value of 3.5×10^{-4} . (9)

Draw a clearly labelled diagram of the pH curve you would expect to obtain when 50 cm^3 of 0.1 M **NaOH** solution is added slowly to 25 cm^3 of a 0.1 M **HCl** solution. Explain by referring to the curve why almost any acid-base indicator can be used in this titration. (12)

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



- (a) Name the molecule in the scheme that contains no tetrahedral carbon atoms. (5)
- (b) Identify (i) an addition reaction, (ii) a substitution reaction, in the scheme above. (6)
- (c) Describe the mechanism of reaction Y. (12)
- (d) State the reagent(s) and condition(s) required to bring about (i) conversion V, (ii) conversion Z. (12)
- (e) Draw a labelled diagram to show how conversion X could be carried out in the school laboratory. (9)
- (f) Conversion W involves a three-step synthesis. Draw the structures of the two organic intermediates in this synthesis. (6)

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

- (a) Define *electronegativity*. (6)

State **two** factors that cause electronegativity values to increase across a period in the periodic table of the elements. (6)

State which of the following compounds contain intermolecular hydrogen bonds:

- (i) hydrogen chloride, **HCl**, (ii) water, **H₂O**, (iii) ammonia, **NH₃**. Justify your answer. (9)

Suggest a reason why the boiling point of ammonia (−33 °C) is significantly lower than that of water (100 °C). (4)

- (b) A chemist synthesised benzoic acid in the laboratory and purified it by recrystallisation. The melting point of the product was measured before and after recrystallisation.
- (i) Describe with the aid of a labelled diagram how the melting point of either the crude product or the recrystallised product could have been measured. (12)
- (ii) Give **two** ways the chemist could have concluded from the melting point measurements that the recrystallised product was purer than the material first prepared. (6)
- (iii) Name the instrumental technique that could have been used to confirm the identity of the product based on its absorption of a unique set of low energy electromagnetic radiations. (3)
- (iv) Give **one** important use of benzoic acid or its salts. (4)

- (c) The balanced equation for the oxidation of ethanol to ethanal using sodium dichromate in acidic conditions is as follows:

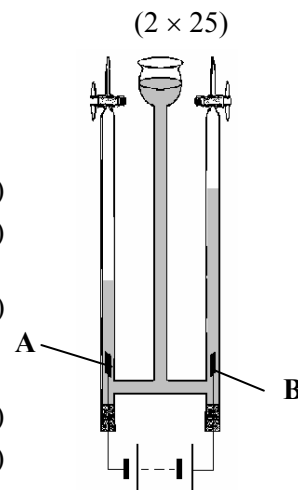


- (i) Deduce the oxidation numbers of chromium in the sodium dichromate reagent and in the chromium sulfate product. (7)
- (ii) State the colour change observed as this reaction proceeds. (3)
- (iii) Describe a test you could carry out to confirm that the organic product is an aldehyde. (9)
- (iv) Give the name and structure of another organic compound that could be formed when ethanol is oxidised using acidified sodium dichromate. (6)

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

(a) The apparatus shown on the right was used to investigate the electrolysis of aqueous sodium sulfate to which a few drops of universal indicator solution had been added. The solution was initially pale green in colour.

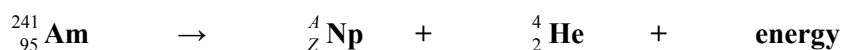
- (i) Name a material suitable for use as the electrodes **A** and **B**. (4)
- (ii) How was the current conducted through the electrolyte? (3)
- (iii) At which electrode, **A** or **B**, did oxidation occur?
Write the equation for the reaction that occurred at this electrode. (9)
- (iv) When a current passed through the electrolyte for 15 minutes, 8.5 cm^3 of gas was collected above the positive electrode. What volume of gas was collected above the negative electrode in the same time? (3)
- (v) At which electrode did a blue colour appear? Justify your answer. (6)



(b) Define (i) *radioactivity*, (ii) the *half-life* of a radioactive isotope. (10)

Americium–241 is a radioactive isotope used in domestic smoke detectors. Americium–241 has a half-life of 432 years and decays by emitting alpha particles to produce neptunium.

Determine the value of *A* and the value of *Z* in the following nuclear equation for the alpha decay of an americium–241 nucleus. (6)



Alpha particles are hazardous to human health. State one risk associated with exposure to alpha radiation. (3)

Explain why the occupants of a house fitted with smoke detectors containing americium–241 are not at risk from alpha radiation emitted by these devices. (3)

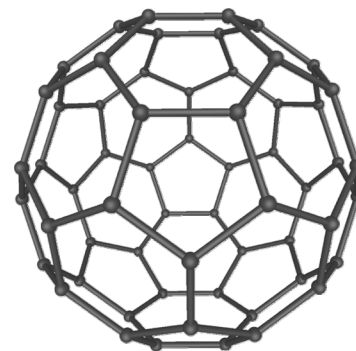
Householders are advised to replace the batteries in smoke detectors regularly. Explain whether or not the americium–241 needs to be replaced regularly also. (3)

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

A

Diamond and graphite are macromolecular crystalline forms of carbon. Explain in terms of bonding

- (i) the hardness of diamond,
- (ii) why graphite is soft and can be used as a lubricant,
- (iii) the electrical conductivity of graphite. (18)



Buckminsterfullerene is another crystalline form of carbon that consists of football shaped clusters of 60 carbon atoms as shown. What type of bond joins the carbon atoms in these ‘bucky balls’? (3)

The spatial arrangement of carbon atoms in each of these three structures was established by analysing the scattering of X-rays by the crystals. What was the surname of the father and son who pioneered this technique? (4)

or

B

Oxygen is produced on an industrial scale by the liquefaction and fractional distillation of air.

- (i) What substances are removed in the purification of the air feedstock before it is liquefied? (4)
- (ii) Describe with the aid of a labelled diagram how the fractional distillation of the pure liquid air is carried out. (9)
- (iii) Explain whether the fractional distillation of air is a continuous or a batch process. (6)
- (iv) Name and give one industrial use of a co-product of the fractional distillation of air. (6)

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