



2007. M34

Coimisiún na Scrúduithe Stáit State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2007

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)

Information

Relative atomic masses: H = 1, He = 4, C = 12, O = 16, Na = 23, S = 32, Cr = 52, Fe = 56

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

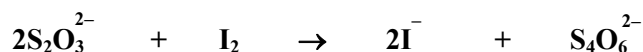
Universal gas constant, $R = 8.3 \text{ J K}^{-1} \text{ mol}^{-1}$

Section A

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

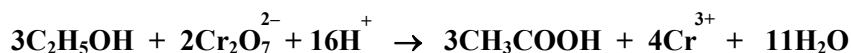
1. A solution of sodium thiosulfate was prepared by weighing out a certain mass of crystalline sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) on a clock glass, dissolving it in deionised water and making the solution up carefully to 500 cm^3 in a volumetric flask. A burette was filled with this solution and it was then titrated against 25.0 cm^3 portions of previously standardised 0.05 M iodine solution in a conical flask. The average titre was 20.0 cm^3 .

The equation for the titration reaction is

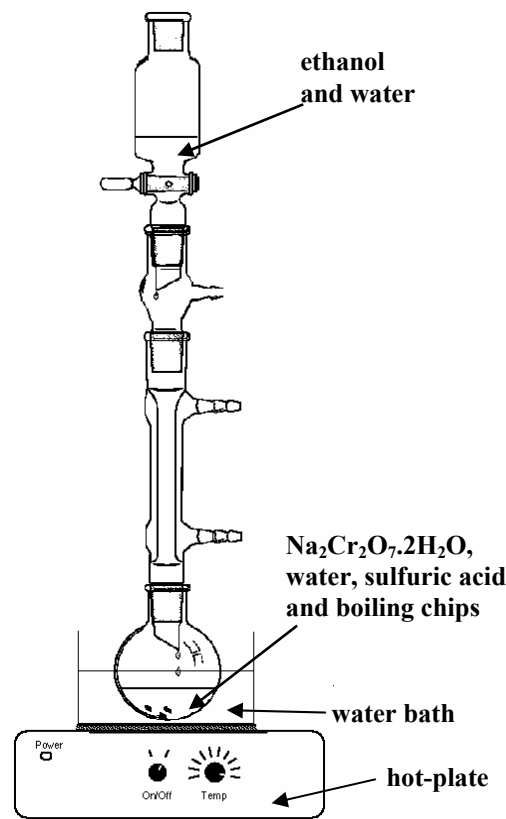


- (a) Sodium thiosulfate is not a primary standard. Explain fully the underlined term. (8)
- (b) Describe how the crystalline thiosulfate was dissolved, and how the solution was transferred to the volumetric flask and made up to exactly 500 cm^3 . (15)
- (c) Pure iodine is almost completely insoluble in water. What must be added to bring iodine into aqueous solution? (3)
- (d) A few drops of freshly prepared starch solution were added near the end point as the indicator for this titration. What sequence of colours was observed in the conical flask from the start of the titration until the end point was reached? (12)
- (e) Calculate the molarity of the sodium thiosulfate solution and its concentration in grams of crystalline sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) per litre. (12)

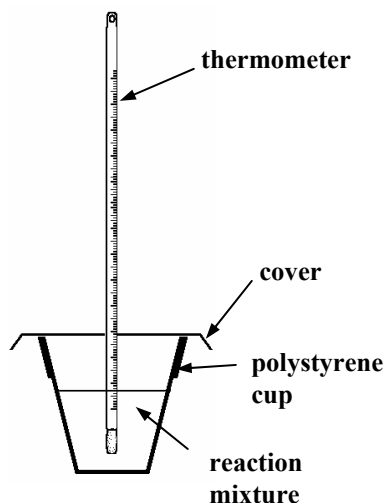
2. A sample of ethanoic acid (CH_3COOH) was prepared by the oxidation of ethanol using the apparatus shown. The reaction is exothermic and is represented by the following equation:



- (a) Before heating the reaction flask, the ethanol and water were added from the tap funnel. State **two** precautions which should be taken when carrying out this addition in order to avoid excessive heat production. (8)
- (b) Describe and explain the colour change observed in the reaction flask as the ethanol was oxidised. (9)
- (c) What was the purpose of heating the reaction mixture under reflux after the addition from the tap funnel was complete? (6)
- (d) Show clearly that the ethanol was the limiting reagent when 8.0 cm^3 of ethanol (density 0.80 g cm^{-3}) was added to 29.8 g of sodium dichromate, $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$. There was excess sulfuric acid present. (12)
- (e) Describe how the ethanoic acid product was isolated from the reaction mixture. (6)
- (f) Describe your observations when a small quantity of solid sodium carbonate was added to a sample of the ethanoic acid produced. Write a balanced chemical equation for the reaction which occurred. (9)



3. In an experiment to measure the heat of reaction for the reaction between sodium hydroxide with hydrochloric acid, a student added 50 cm³ of 1.0 M HCl solution to the same volume of 1.0 M NaOH solution in a polystyrene foam cup.



- (a) To achieve an appreciable temperature rise during the reaction, quite concentrated solutions of acid and base, carrying the label illustrated, were used. What word describes the chemical hazard illustrated in this label? State **one** precaution the student should take when using these solutions. (8)



- (b) The student had a choice of using either a graduated cylinder or a burette to measure out the solutions used in this experiment. Which piece of apparatus should have been used to achieve the more accurate result? (3)
- (c) If the hydrochloric acid and sodium hydroxide solutions had been stored at slightly different temperatures, explain how the initial temperature of the reaction mixture could have been obtained. (6)
- (d) List **three** precautions which should have been taken in order to obtain an accurate value for the highest temperature reached by the reaction mixture. (9)
- (e) What was the advantage of mixing the solutions in a polystyrene foam cup rather than in a glass beaker or in a metal calorimeter? (3)
- (f) Calculate the number of moles of acid neutralised in this experiment. Taking the total heat capacity of the reaction mixture used in this experiment as 420 J K⁻¹, calculate the heat released in the experiment if a temperature rise of 6.7 °C was recorded. Hence calculate the heat of reaction for



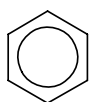
- (g) Name the piece of apparatus used in industry to accurately measure the heats of combustion of foods and fuels. (3)

Section B

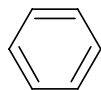
[See page 1 for instructions regarding the number of questions to be answered].

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

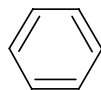
- (a) Define *atomic (covalent) radius*.
- (b) What is the principal use made of oxygenates such as methyl *tert*-butyl ether, MTBE, in the petrochemicals industry?
- (c) Distinguish between sigma (σ) and pi (π) covalent bonding.
- (d) What is meant by *heterogeneous* catalysis?
- (e) How many iron atoms should be consumed daily to meet the recommended daily intake of iron in the diet of 0.014 g?
- (f) Name the two reagents used in the brown ring test for the nitrate ion.
- (g) Name and draw the structure of a carboxylic acid that is widely used as a food preservative.
- (h) A 500 cm³ can of beer contains 21.5 cm³ of ethanol. Calculate its % alcohol, i.e. the concentration of alcohol in the beer as a % (v/v).
- (i) Explain in terms of bonding why it is more correct to represent the benzene molecule as



instead of



or



- (j) Ultraviolet absorption spectroscopy can be used in the quantitative analysis of some organic compounds (e.g. drug metabolites and plant pigments). What is the underlying principle of this analytical technique?
 - (k) Answer part **A** or **B**.
 - A** The use of CFCs as refrigerant gases has been discontinued. Name a group of substances used to replace CFCs as refrigerant gases.
- or*
- B** Name the electrochemist who was the first to isolate the elements sodium and potassium in 1807 by passing electricity through sodium hydroxide and potassium hydroxide, respectively.
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5. (a) Define *energy level*. (5)

Write the electron configuration (*s, p*) for the sulfur atom in its ground state, showing the arrangement in atomic orbitals of the highest energy electrons. (6)

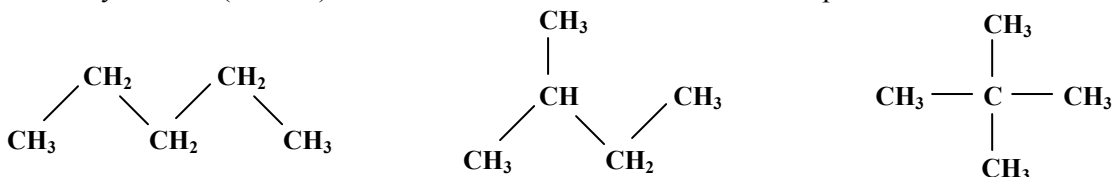
State how many (i) energy levels, (ii) orbitals, are occupied in a sulfur atom in its ground state. (6)

- (b) Use electronegativity values (Mathematical Tables p 46) to predict the type of bond expected between hydrogen and sulfur. (6)
Write the chemical formula for hydrogen sulfide. (6)
Use clear dot and cross diagrams to show the bonding in hydrogen sulfide. (6)
 - Would you expect the hydrogen sulfide molecule to be *linear* or *non-linear* in shape? (6)
Justify your answer. (6)
 - (c) Hydrogen sulfide has a boiling point of 212.3 K and water has a boiling point of 373 K. (6)
Account for the difference in the boiling points of these substances. (6)
Would you expect hydrogen sulfide to be soluble in water? Explain your answer. (6)
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6. Useful hydrocarbons are obtained by the fractional distillation of crude oil, which itself has little or no direct use. Hydrocarbons are excellent fuels.

(a) In which fraction of crude oil do pentane and its isomers occur? (5)

Give the systematic (IUPAC) name of each of the structural isomers of pentane shown below. (9)



Which of these isomers would you predict to have the lowest octane number?

Justify your choice in terms of the structural features of the molecules. (9)

Write a balanced equation for the combustion of pentane (C_5H_{12}) in excess oxygen. (6)

(b) Naphtha and gas oil are two of the hydrocarbon fractions obtained from the fractional distillation of crude oil. How do the molecules of the naphtha fraction differ from the molecules of the gas oil fraction? (3)

Explain with the aid of a labelled diagram how naphtha (b.p. approximately $100\text{ }^\circ\text{C}$) is separated from gas oil (b.p. approximately $300\text{ }^\circ\text{C}$) in the fractional distillation of crude oil. (9)

Bitumen is a residue fraction obtained from crude oil. Give **one** use for bitumen. (3)

(c) What is catalytic cracking? What is its economic importance in oil refining? (6)

7. (a) Define (i) *acid*, (ii) *conjugate pair*, according to the Brønsted-Lowry theory. (8)

Identify the two conjugate pairs in the following dissociation of nitrous acid (HNO_2):



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

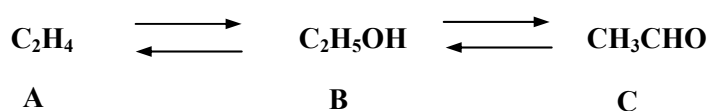
(b) Calculate the pH of 0.1 M nitrous acid (HNO_2); the value of the acid dissociation constant (K_a) for nitrous acid is 5.0×10^{-4} .

What is the pH of a nitric acid (HNO_3) solution of the same concentration? (15)

(c) *Eutrophication* in water may result from the addition of large quantities of nitrate fertilizers to it. Describe the processes occurring in the water leading to eutrophication. (9)

(d) Explain how heavy metal ions are removed from large quantities of water. (6)

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



(a) Name the homologous series (i) to which **A** belongs, (ii) to which **C** belongs. (8)

(b) The conversion of **B** to **A** is an elimination reaction. What two features of elimination reactions are illustrated by this conversion? (6)

(c) Name the reagent and the catalyst required to convert **C** to **B**. (6)

(d) Draw full structural formulas for **B** and **C**. Indicate any carbon atom in either structure that has planar geometry. List the bonds broken in **B** and the bond made in **C** in the synthesis of **C** from **B**. (18)

(e) After carrying out a laboratory conversion of **B** to **C**, how could you test the product to confirm the formation of **C**? (9)

(f) Compound **C** is formed as a metabolite of compound **B** in the human body. How does compound **B** come to be present in the body? (3)

9. (a) Define the *rate of a chemical reaction*.
Why does the rate of chemical reactions generally decrease with time? (8)
- (b) The rate of reaction between an excess of marble chips (CaCO_3) (diameter 11 – 15 mm) and 50 cm³ of 2.0 M hydrochloric acid was monitored by measuring the mass of carbon dioxide produced.

The table shows the total mass of carbon dioxide gas produced at stated intervals over 9 minutes.

Time/minutes	0.0	1.0	2.0	3.0	4.0	5.5	7.0	8.0	9.0
Mass of CO_2 /g	0.00	0.66	1.20	1.60	1.90	2.10	2.18	2.20	2.20

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

Use the graph to determine

- (i) the instantaneous rate of reaction in grams per minute at 4.0 minutes,
(ii) the instantaneous rate of reaction at this time in moles per minute. (9)
- (c) Describe and explain the effect on the rate of reaction of repeating the experiment using 50 cm³ of 1.0 M hydrochloric acid and the same mass of the same size marble chips. (6)
- (d) Particle size has a critical effect on the rate of a chemical reaction.
(i) Mark clearly on your graph the approximate curve you would expect to plot if the experiment were repeated using 50 cm³ of 2.0 M HCl and using the same mass of marble chips but this time with a diameter range of 1 – 5 mm. (6)
(ii) Dust explosions present a risk in industry. Give **three** conditions necessary for a dust explosion to occur. (9)

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

- (a) (i) Write the equilibrium constant (K_c) expression for the reaction (7)



- (ii) Three moles of nitrogen gas and nine moles of hydrogen gas were mixed in a 1 litre vessel at a temperature T . There were two moles of ammonia in the vessel at equilibrium. Calculate the value of K_c for this reaction at this temperature. (12)
- (iii) Henri Le Chatelier, pictured on the right, studied equilibrium reactions in industry in the late 19th century. According to Le Chatelier's principle, what effect would an increase in pressure have on the yield of ammonia at equilibrium? Explain. (6)



- (b) (i) State *Avogadro's law*. (7)

- (ii) Carbon dioxide is stored under pressure in liquid form in a fire extinguisher. Two kilograms of carbon dioxide are released into the air as a gas on the discharge of the fire extinguisher. What volume does this gas occupy at a pressure of 1.01×10^5 Pa and a temperature of 290 K? (9)

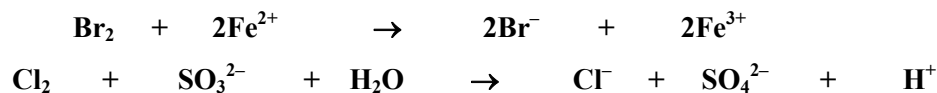


What mass of helium gas would occupy the same volume at the same temperature and pressure? (6)

- (iii) Give **one** reason why carbon dioxide is more easily liquefied than helium. (3)

- (c) The halogens are good oxidising agents.

- (i) How does the oxidation number of the oxidising agent change during a redox reaction? (4)
- (ii) Assign oxidation numbers in each of the following equations to show clearly that the halogen is the oxidising agent in each case. (12)



Hence or otherwise balance the second equation. (6)

- (iii) Why does the oxidising ability of the halogens decrease down the group? (3)

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

(2 × 25)

(a) In 1910 Rutherford (pictured right) and his co-workers carried out an experiment in which thin sheets of gold foil were bombarded with alpha particles. The observations made during the experiment led to the discovery of the atomic nucleus.



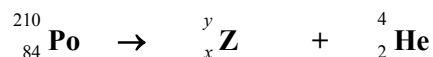
(i) Describe the model of atomic structure which existed immediately *prior* to this experiment. (7)

(ii) In this experiment it was observed that most of the alpha particles went straight through the gold foil. Two other observations were made. State these other observations and explain how each helped Rutherford deduce that the atom has a nucleus. (12)

In November 2006 former Soviet agent, Alexander Litvinenko, died in London. The cause of his death was identified as radiation poisoning by polonium-210.



(iii) Polonium-210 decays emitting an alpha particle. Copy and complete the equation for the alpha-decay of polonium-210, filling in the values of *x* (atomic number), *y* (mass number) and **Z** (elemental symbol). (6)



(b) An equimolar mixture of chlorine and methane react together at room temperature only when ultra-violet light is present.

(i) Explain clearly the role of the ultraviolet light in the reaction between chlorine and methane. (7)

(ii) Name the two main products of the reaction between chlorine and methane. (6)

(iii) Account for traces of ethane found in the product mixture. (6)

Chlorine reacts with ethene at room temperature even in the dark.

(iv) Name the type of mechanism which occurs in the reaction between chlorine and ethene. (3)

(v) Give a use for chloroalkanes. (3)

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

A

Environmentalists are concerned about the increasing abundance of carbon dioxide in the atmosphere.

(i) State one important way carbon dioxide is constantly added to the atmosphere. (4)

(ii) Carbon dioxide is a greenhouse gas. It has been assigned a greenhouse factor of 1. What use is made of the “*greenhouse factor*” of a gas? (6)

(iii) Name **two** other greenhouse gases. (6)

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

OR

B

Aluminium, sodium chloride and graphite are all crystalline solids.

For each of these substances, name the type of crystal formed. (7)

Explain clearly, in terms of bonding, why

(i) aluminium is a good conductor of electricity,

(ii) sodium chloride is soluble in water,

(iii) graphite is soft and slippery. (18)

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