Coimisiún na Scrúduithe Stáit
State Examinations Commission

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LEAVING CERTIFICATE EXAMINATION, 2004

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CHEMISTRY - HIGHER LEVEL

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TUESDAY, 22 JUNE – AFTERNOON 2.00 TO 5.00

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400 MARKS

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Answer **eight** questions in all

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

All questions carry equal marks (50)

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Information

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

Molar volume at room temperature and pressure = 24.0 litres

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

Section A

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

1. In an experiment to determine the total hardness of a water sample containing both calcium and magnesium ions, a solution of the reagent **edta** (ethylenediaminetetraacetic acid) in the form of its disodium salt (represented by Na_2H_2Y) was titrated against a sample of the water using a suitable indicator. The reaction between the ions (represented by M^{2+}) in the hard water and the **edta** reagent may be represented as

$$M^{2+} \quad + \quad H_2Y^{2-} \quad \longrightarrow \quad MY^{2-} \quad + \quad 2H^+$$
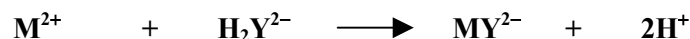
(a) Name a suitable indicator for this titration.
    What colour change is observed at the end point of the titration using this indicator? (8)

(b) Describe the correct procedure for rinsing the burette and filling it with **edta** reagent. (15)

(c) The addition of a small quantity of another solution to the water in the conical flask is essential before commencing the titration. What solution must be added and what is its purpose? (6)

(d) In the experiment it was found that 100 cm³ portions of the water required an average titre of 8.10 cm³ of 0.010 M **edta** solution. Calculate the total hardness in
    (i) moles per litre,
    (ii) grams per litre expressed in terms of $CaCO_3$ and
    (iii) p.p.m. expressed in terms of $CaCO_3$. (15)

(e) A whitish deposit is often found on the insides of kettles in hard water districts. If some of this deposit is scraped into a test tube and dilute hydrochloric acid is added a reaction is observed. Write a balanced equation for this reaction. (6)

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2. The diagram shows the experimental set-up used by a group of students to prepare a sample of ethene from ethanol and to collect the ethene produced.
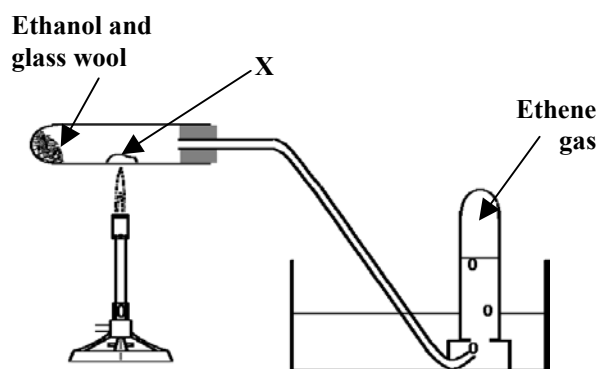
(a) What is the function of the glass wool? (5)
    Identify the solid **X** <u>and</u> describe its appearance. (6)

(b) State and explain **two** safety precautions which should be observed when carrying out the student experiment. (12)

(c) Write a balanced equation for the reaction involved in this preparation. (6)

(d) If the ethene produced is bubbled through an acidified solution of potassium manganate(VII), the solution is decolorised showing that ethene is *unsaturated*. What is meant by the term *unsaturated*? Describe how you would carry out another test to confirm that ethene is unsaturated. (12)

(e) Describe the flame that would be observed when a combustion test is carried out on a sample of ethene gas. Write a balanced equation for the combustion of ethene in excess oxygen. (9)

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3. (*a*) A sample of impure benzoic acid was recrystallised as follows: 2.5 g of the impure benzoic acid was weighed out and dissolved in the minimum amount of hot water. The hot solution was filtered and the filtrate was allowed to cool and recrystallise. The recrystallised benzoic acid was isolated by filtration. After drying, 2.25 g of purified acid were obtained.

   (*i*)   Why is it important to use the minimum amount of hot water in the procedure? (5)

   (*ii*)   Indicate clearly the stage of the recrystallisation procedure at which *insoluble* impurities were removed and how their removal was achieved. Indicate also the stage at which *soluble* impurities were removed and how their removal was achieved. (12)

   (*iii*) How could you have ensured that the recrystallisation was complete? (3)

   (*iv*)   How could the crystals have been dried? (3)

   (*v*)   What was the percentage yield of purified benzoic acid? (3)

(*b*) Melting points of samples of the impure and recrystallised benzoic acid were taken and compared.

   (*i*)   Describe with the aid of a labelled diagram how you would have measured the melting point of one of these samples. (15)

   (*ii*)   Give **two** ways in which you would expect the melting point of the impure benzoic acid to differ from that of the purified acid. (6)

   (*iii*) State **one** use of benzoic acid and its salts. (3)

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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 *relative atomic mass*.

   (*b*) Account for the difference in the shapes of the ammonia (NH_3) and boron trifluoride (BF_3) molecules.

   (*c*) The boiling points of hydrogen and oxygen are 20.0 K and 90.2 K respectively. Account for the higher boiling point of oxygen.

   (*d*) State *Charles' law*.

   (*e*) Write (*i*) the conjugate acid and (*ii*) the conjugate base of HPO_4^{2-} .

   (*f*) How are heavy metals, e.g. mercury, removed from industrial waste before it is discharged into rivers, lakes or the sea?

   (*g*) What is the oxidation number (*i*) of oxygen in H_2O_2 and (*ii*) of bromine in $KBrO_3$?

   (*h*) What is the percentage by mass of iron in iron(III) oxide (Fe_2O_3)?

   (*i*) State <u>and</u> explain the colour observed at the negative electrode in the electrolysis of aqueous potassium iodide, containing a little phenolphthalein indicator, using inert electrodes.

   (*j*) How could the presence of sulfite ions in aqueous solution be detected?

   (*k*) Answer part **A** <u>or</u> **B**.

   A   How is oxygen gas produced industrially?

   or

   B   How does the anodising of aluminium protect it from corrosion?

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5. (*a*) Write the electron configuration (*s, p,* etc.) of the nitrogen atom. (5)

   Show, using dot and cross diagrams, the bond formation in a nitrogen molecule.
   Describe the bonding in the nitrogen molecule in terms of sigma (σ) and pi (π) bonding. (9)

   What type of intermolecular forces would you expect to find in nitrogen gas? Explain your answer. (6)

   (*b*) Define *first ionisation energy*. (9)

   There is a general increase in first ionisation energy across a period of the periodic table.
   State the **two** principal reasons for this trend. (6)

   The table shows the first and second ionisation energies of nitrogen, oxygen, neon and sodium.

   Account for the decrease in first ionisation energy between nitrogen and oxygen.

   Explain why the second ionisation energy of sodium is significantly (about nine times) higher than the first while the increase in the second ionisation energy of neon compared to its first is relatively small (less than twice the first). (15)

Element	First ionisation energy (kJ mol^{-1})	Second ionisation energy (kJ mol^{-1})
Nitrogen	1400	2860
Oxygen	1310	3390
Neon	2080	3950
Sodium	494	4560

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6. (*a*) Define (*i*) *heat of formation of a substance,* (*ii*) *octane number of a fuel.* (11)

(*b*) The combustion of methane is described by the following balanced equation.

$$CH_{4(g)} \quad + \quad 2O_{2(g)} \quad \longrightarrow \quad CO_{2(g)} \quad + \quad 2H_2O_{(l)} \qquad \Delta H \;=\; -890.4 \text{ kJ mol}^{-1}$$

The standard heats of formation of carbon dioxide and water are −394 and −286 kJ mol^{-1} respectively. Calculate the heat of formation of methane. (12)

(*c*) Methane is an excellent fuel. Give **two** properties of methane which account for its usefulness as a fuel. Natural gas is a rich source of methane. Why are mercaptans often added to natural gas? (9)

(*d*) Methane is often found in gas fields which occur in association with crude oil deposits. Crude oil is fractionated in order to obtain more useful products. Outline clearly how the fractionation process is carried out. (12)

(*e*) Identify **two** structural features of a hydrocarbon fuel which affect its octane number. (6)

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7. (*a*) Copy into your answer book the structure of the ester shown and indicate clearly on your diagram a carbon atom which is in planar geometry in the molecule, and also a carbon atom which is in tetrahedral geometry in the molecule. (8)
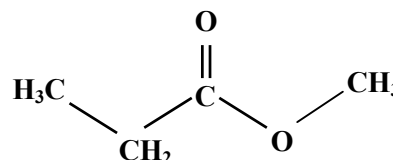
(*b*) Give the names of the alcohol <u>and</u> of the carboxylic acid from which the ester shown in the diagram is synthesised. What organic reaction type describes this esterification reaction? (15)

(*c*) The carboxylic acid you were asked to name in (*b*) may itself be synthesised in two steps from an alcohol.

    (*i*)   Identify the alcohol from which the carboxylic acid is derived.
    (*ii*)   Give the name <u>and</u> structure of the intermediate organic compound in this synthesis.
    (*iii*) Identify the type of organic reaction involved in each step.
    (*iv*) Identify the inorganic reagents which may be used in this synthesis. (21)

(*d*) State **two** common uses of esters. (6)

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8. (*a*) Define the *rate of a chemical reaction.* (5)

Explain why increasing the temperature has a significant effect on the rate of a reaction. (6)

(*b*) The diagram shows a reaction profile diagram for an endothermic reaction. Name the quantities of energy marked **A** and **B**.

Copy this diagram into your answer book and indicate clearly on your diagram the likely effect of adding a catalyst on the energy profile for the reaction. (12)
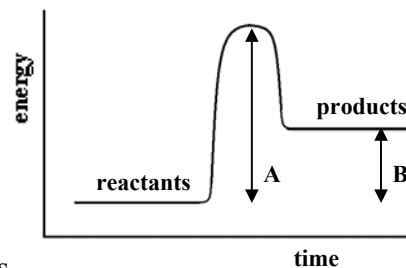
(*c*) Catalytic converters are fitted to all modern cars with petrol engines. Name **two** elements used as catalysts in a catalytic converter. Name **one** substance which poisons the catalysts in a catalytic converter. (9)

(*d*) The oxidation of potassium sodium tartrate by hydrogen peroxide catalysed by cobalt(II) ions provides evidence for the intermediate formation theory of catalysis. State the observations you would make when carrying out this experiment. Explain how these observations provide evidence for the intermediate formation theory. (18)

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9. (*a*) What is meant by *chemical equilibrium*? Why is it described as a *dynamic* state? (8)

Consider the following reversible chemical reaction:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \quad \Delta H = -92.4 \text{ kJ}$$
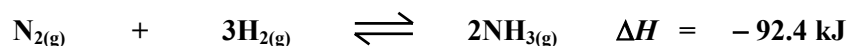
(*b*) Use Le Chatelier's principle to predict the levels (high or low) of temperature and pressure needed to maximise the yield of ammonia when equilibrium is established. Give a reason (*i*) for the temperature level you have predicted, (*ii*) for the level of pressure you have predicted. (12)

(*c*) Are the temperature levels predicted using Le Chatelier's principle actually used to maximise ammonia yield in industry? Explain your answer. (6)

(*d*) What is the effect of a catalyst on a reversible reaction? (6)

(*e*) In an experiment 6.0 moles of nitrogen and 18.0 moles of hydrogen were mixed and allowed to come to equilibrium in a sealed 5.0 litre vessel at a certain temperature. It was found that there were 6.0 moles of ammonia in the equilibrium mixture.
Write the equilibrium constant expression for the reaction and calculate the value of the equilibrium constant (K_c) at this temperature. (18)

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

(*a*) Hydrochloric acid is severely corrosive to skin and eyes and toxic by inhalation or ingestion. It should be handled carefully and stored safely.

The entire contents of a bottle containing 2.5 litres of concentrated hydrochloric acid were accidentally spilled in a laboratory. The spilled acid was neutralised by adding solid powdered sodium carbonate. The neutralisation reaction is described by the following equation.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

The spilled acid was a 36% (w/v) solution of hydrogen chloride in water.

(*i*) Calculate the number of moles of hydrochloric acid spilled. (10)

(*ii*) What was the minimum mass of anhydrous sodium carbonate required to completely neutralise all of the spilled hydrochloric acid? (9)

(*iii*) What volume of carbon dioxide in litres, at room temperature and pressure, was produced in this neutralisation reaction? (6)

(*b*) Describe how Bohr used line emission spectra to explain the existence of energy levels in atoms. (13)

(*i*) Why does each element have a unique line emission spectrum? (6)

(*ii*) The fact that each element has a unique line spectrum forms the basis for an instrumental technique which can be used to detect heavy metals and to measure their concentrations in a soil or a water sample. Name the instrumental technique. (3)

(*iii*) Bohr's atomic theory was later modified. Give **one** reason why this theory was updated. (3)

(*c*) State *Avogadro's law*. (5)

(*i*) What is an ideal gas? (5)

(*ii*) State **one** reason why ammonia gas deviates from ideal gas behaviour. (3)

(*iii*) A small quantity of the volatile organic solvent propanone (C_3H_6O) evaporates at room temperature and pressure. Use the equation of state for an ideal gas to calculate the volume, in litres, of propanone vapour formed when 0.29 g of liquid propanone evaporates taking room temperature as 20 ºC and room pressure as 101 kPa. (12)

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

(*a*) Define radioactivity.   (6)

    (*i*)   State **two** properties of beta (β) particles.   (6)

    (*ii*) Write an equation for the nuclear reaction involved in the beta decay of ^{14}C (carbon-14).   (6)

    (*iii*) Explain how the carbon-14 isotope allows certain archaeological discoveries to be dated.   (7)

(*b*) Define pH.   (7)
    (*i*)   What are the limitations of the pH scale?   (6)
    (*ii*) Calculate the approximate pH of a vinegar solution that contains 4.5 g of ethanoic acid per 100 cm^3. The value of K_a for ethanoic acid is 1.8×10^{-5}.   (12)

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

A

Write a brief note on the contribution made to our understanding of crystal structures by
    (*i*)   Lawrence and William Bragg,
    (*ii*) Dorothy Hodgkin.   (7)

Lawrence and William Bragg

What type of crystal is formed by iodine <u>and</u> what are the binding forces in the crystal?   (6)

Explain
    (*i*)   why metals are generally good conductors of electricity,
    (*ii*) why most ionic crystals dissolve in water.   (12)

Dorothy Hodgkin

or

B

The *greenhouse effect* is a natural phenomenon but its effects have been enhanced by human activity over the past 200 years.

    (*i*)   Explain the term *greenhouse effect*.   (7)

    (*ii*) Identify **one** gas in the atmosphere which makes a significant contribution to the greenhouse effect.   (3)

    (*iii*) In relation to the gas you have identified in (*ii*), mention a type of human activity which has been a major contributor to the increased levels of this gas in the atmosphere.   (3)

    (*iv*) Identify **one** gas, found in the atmosphere, which is not a greenhouse gas.   (3)

    (*v*) State **three** probable consequences of an increased greenhouse effect which have been suggested by environmental scientists.   (9)

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