Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2009

CHEMISTRY - HIGHER LEVEL

TUESDAY, 16 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, Fe = 56

Molar volume at s.t.p. = 22.4 litres

Avogadro constant = 6×10^{23} mol^{-1}

Section A

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

1. The Fe^{2+} content of iron tablets was determined by titration with a freshly standardised solution of potassium manganate(VII), **$KMnO_4$.**

The equation for the titration reaction is

$$\mathbf{5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O}$$

(*a*) Why are iron tablets sometimes medically prescribed? (5)

(*b*) Why must potassium manganate(VII) solutions be standardised? Why was it necessary to standardise the potassium manganate(VII) solution *immediately* before use in the titration? What reagent is used for this purpose? (9)

(*c*) Describe how exactly 250 cm^3 of Fe^{2+} solution was prepared from five iron tablets, each of mass 0.325 g. Why was some dilute sulfuric acid used in making up this solution? (12)

(*d*) Explain why additional dilute sulfuric acid must be added to the titration flask before each titration is carried out. (6)

(*e*) On average, 18.75 cm^3 of 0.01 M potassium manganate(VII) was required to react with 25.0 cm^3 portions of the iron solution prepared from the five tablets.
Calculate
(*i*) the molarity of the Fe^{2+} solution,
(*ii*) the total mass of iron in the 250 cm^3 of solution,
(*iii*) the percentage by mass of iron in the tablets. (18)

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2. Ethene can be prepared in the school laboratory using the arrangement of apparatus shown in Diagram 1.

Ethyne can be prepared in the school laboratory using the arrangement of apparatus shown in Diagram 2.

(*a*) Give the name <u>or</u> chemical formula of the solid **X** used in the preparation of ethene.
What is the colour of this solid? (5)

(*b*) Write a balanced equation for the reaction involved in the preparation of ethene. What term describes this type of reaction? (6)

(*c*) State **three** precautions that should be observed when carrying out the preparation of ethene by this method. (9)

(*d*) Give the name <u>or</u> formula of the solid **Y** used in the preparation of ethyne in the school laboratory.
Describe the appearance of this solid. (6)

(*e*) Both ethene and ethyne are described as *unsaturated*.
What does this mean? Describe a test you could carry out on a sample of either gas to show that it is unsaturated.
What would you observe during the test? (9)

(*f*) Both ethene and ethyne can be burned in air.
What is the most noticeable difference seen when these combustions are carried out in a school laboratory?
Write a balanced equation for the complete combustion of either gas. (9)

(*g*) Give (*i*) a major use of ethene,
(*ii*) a major use of ethyne. (6)

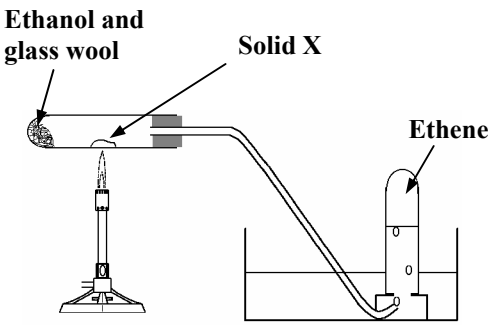


Diagram 1

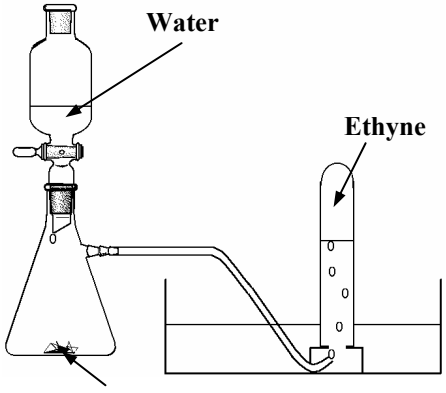
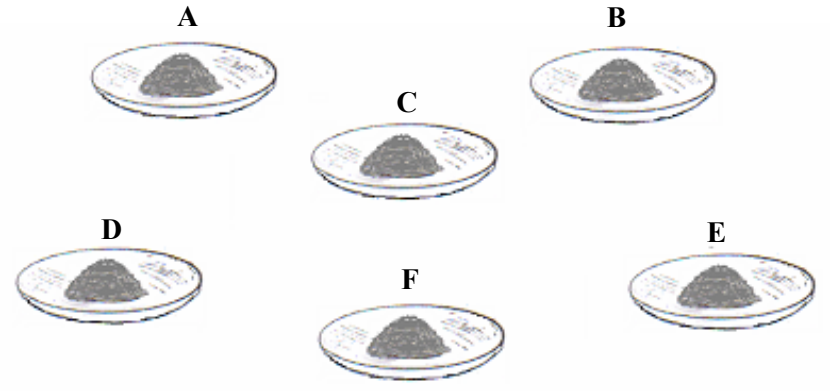


Diagram 2

3. The clock glasses shown in the diagram contained pure samples of the following salts: **KCl**, **KNO_3**, **$Na_2HPO_4.12H_2O$**, **$Na_2SO_3.7H_2O$**, **$NaHCO_3$** and **$Na_2SO_4.10H_2O$**. Each clock glass (**A – F**) contained a different salt. A student was provided with standard laboratory apparatus and reagents, and was asked to identify the six salts.



(*a*) Describe how the student could have distinguished between the samples that contained potassium ions and those that contained sodium ions using the flame test technique. (11)

(*b*) Which of the substances listed above was identified by the addition of silver nitrate, **$AgNO_3$**, solution to a solution of each sample in turn? What observation indicated a positive test result? (6)

(*c*) One of the samples gave a brown ring when a little concentrated sulfuric acid was carefully poured down the inside of a slanting test tube which contained a solution of the salt, together with another reagent. What was the other reagent? Which salt was identifiable by the appearance of a brown ring? (6)

(*d*) Describe how you would test the samples for the presence of the phosphate anion. (9)

(*e*) Having completed the tests referred to in (*a*) – (*d*) above the student should have positively identified three of the salts. A solution of barium chloride, **$BaCl_2$**, was then added to solutions of each of the three remaining samples in turn. A white precipitate was produced in two cases. Write a balanced equation for either **one** of the two reactions that occurred.

The student then added dilute hydrochloric acid to the precipitates.
What would the student have observed and what conclusion should have been drawn regarding the identities of the two salts? (12)

(*f*) The student was able to identify the last salt by a process of elimination. Suggest a way of confirming the identity of this salt. (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*) The scientist pictured on the right used charged oil drops to determine the size of the charge on a sub-atomic particle. Name the scientist, and the sub-atomic particle involved in his experiments.

(*b*) What change occurs in the nucleus of an atom when it undergoes beta emission?

(*c*) State the *Heisenberg uncertainty principle*.

(*d*) Define *bond energy*.

(*e*) Define a conjugate pair according to the Brønsted-Lowry theory.

(*f*) Calculate the pH of a 0.025 M solution of nitric acid.

(*g*) When water that contains temporary hardness is boiled in a kettle, scale is formed on the heating element. Identify the chemical that is the main component of this scale.

(*h*) Draw the structures of two acidic functional groups that occur in organic compounds.

(*i*) Complete and balance the equation: $\mathbf{C_2H_6} + \mathbf{Cl_2} \xrightarrow{\text{uv light}}$

(*j*) Identify the chemical hazard associated with each of the following warning symbols.

(*i*) 

(*ii*) 

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

A What use is made of the organometallic catalysts discovered by Karl Ziegler in 1953?

or

B Write a balanced chemical equation for **one** of the following reactions from syllabus case studies based on the chemical industry:

(*i*) the synthesis of urea from ammonia;

(*ii*) the combustion of ammonia in air;

(*iii*) the formation of magnesium hydroxide from slaked lime and seawater.

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5. (*a*) Define *first ionisation energy* of an element. (8)

(*b*) Use the values on page 45 of the Mathematics Tables to plot a graph on graph paper of first ionisation energy *versus* atomic number for the elements with atomic numbers from 10 to 20 inclusive. (12)

(*c*) Account fully for

(*i*) the general increase in ionisation energy values across the third period of the Periodic Table,
(*ii*) the peaks which occur in your graph at elements 12 and 15,
(*iii*) the sharp decrease in ionisation energy value between elements 18 and 19. (18)

(*d*) Write the *s*, *p* electron configuration for the potassium atom.

Hence state how many (*i*) energy sub-levels, (*ii*) individual orbitals, are occupied by electrons in a potassium atom.

Explain why there are electrons in the fourth main energy level of potassium although the third main energy level is incomplete. (12)

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6. (*a*) Define (*i*) hydrocarbons, (*ii*) structural isomers. (8)

(*b*) Give a use for the kerosene fraction obtained when crude oil is fractionated.
Explain why some of the kerosene produced in oil refining is subjected to catalytic cracking. (9)

(*c*) Straight chain molecules of $\mathbf{C_{13}H_{28}}$ occur in the kerosene fraction. Upon cracking a molecule of $\mathbf{C_{13}H_{28}}$, a $\mathbf{C_2H_4}$ molecule, a $\mathbf{C_4H_8}$ molecule and an unbranched alkane molecule are obtained.
Identify this unbranched alkane molecule and state its octane number.
Draw structures for three of the isomers of $\mathbf{C_4H_8}$. (15)

(*d*) Name two other processes carried out in oil refineries to modify hydrocarbon structures. (6)

(*e*) The combustion of one of the $\mathbf{C_4H_8}$ isomers is described by the following balanced equation.

$$\mathbf{C_4H_8 + 6O_2 \rightarrow 4CO_2 + 4H_2O} \qquad \mathbf{\Delta H = -2710\ kJ\ mol^{-1}}$$

The standard heats of formation of water and carbon dioxide are –286 and –394 kJ mol^{-1}, respectively. Calculate the heat of formation of this $\mathbf{C_4H_8}$ isomer. (12)

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7. (*a*) According to the EPA (Environmental Protection Agency) publication 'The Provision and Quality of Drinking Water in Ireland (2006-2007)': *Drinking water must be clean and wholesome. That means it must meet the relevant water quality standards and must not contain any other substance or micro-organism in concentration or numbers that constitute a potential danger to human health.*

(*i*) Describe how suspended solids are removed in water treatment.

(*ii*) What treatment is carried out to ensure low levels of micro-organisms in drinking water?

(*iii*) What problems would arise if the pH of a public water supply were outside the range 6 – 8?

(*iv*) EU standards specify that the concentration of lead (in the form of Pb^{2+}) in drinking water must be below 10 µg/l (micrograms per litre). Why must the Pb^{2+} concentration be kept so low? How are heavy metal ions like Pb^{2+} removed from large quantities of water? (23)

(*b*) Quoting from the EPA website: *The main threat to surface water quality is eutrophication, which is the over-abundant growth of plants and algae arising from excess nutrients in the water.*

(*i*) What are the nutrients referred to above? At what stage of sewage treatment are their levels lowered so that eutrophication does not occur downstream from sewage works? (9)

(*ii*) A sample of brewery effluent was diluted from 50 cm^3 to 5.0 litres with well-aerated pure water. The dissolved oxygen concentration of half the sample was measured immediately; the other half was stored under suitable conditions and its dissolved oxygen concentration was measured later. Concentrations of dissolved oxygen of 9.8 ppm and 4.7 ppm, respectively, were recorded.
What are the suitable conditions for, and the duration of, storage of the second sample?
Calculate the BOD of the brewery effluent. (18)

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8. Answer the questions below with reference to the compounds **A** – **D** in the table on the right.

A	$\mathbf{C_2H_5OH}$
B	$\mathbf{CH_3CHO}$
C	$\mathbf{CH_3COOH}$
D	$\mathbf{CH_3COOC_2H_5}$

(*a*) Give the IUPAC name for each of the compounds **A** – **D**. (12)

(*b*) Name the family (homologous series) of organic compounds to which compound **B** belongs. Name the aromatic compound, found in almond kernels, that has the same functional group as compound **B**. (9)

(*c*) Which of the compounds **A** – **D** is present in concentrations of about 40% (v/v) in whiskey? Which of the other compounds is formed as the primary metabolite of this compound in the human body? (6)

(*d*) Describe what is observed when a small amount of sodium carbonate is added to a test tube containing an aqueous solution of compound **C**. Write a balanced equation for the reaction. Name the flavouring agent that consists of an approximately one molar solution of compound **C**. Express the concentration of a one molar solution of **C** in terms of % (w/v). (15)

(*e*) Draw the full structural formula for compound **D** and clearly label each carbon atom that has tetrahedral geometry. (8)

9. (*a*) Explain (*i*) activation energy, (*ii*) effective collision. (8)

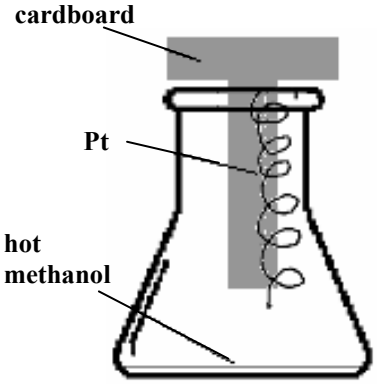
The effect of temperature on the rate of a chemical reaction was investigated using dilute solutions of hydrochloric acid and sodium thiosulfate. Suitable volumes and concentrations of the solutions were used. The reaction is represented by the following balanced equation.

$$2HCl + Na_2S_2O_3 \rightarrow 2NaCl + H_2O + S + SO_2$$

Describe how the time for the reaction between the solutions of hydrochloric acid and sodium thiosulfate was obtained at room temperature. (6)

In a reaction mixture what effect, if any, does an increase in temperature of 10 K have on each of the following:
(*i*) the number of collisions, (*ii*) the effectiveness of the collisions, (*iii*) the activation energy. (9)

(*b*) The catalytic oxidation of methanol using platinum wire is illustrated in the diagram.



State **one** observation made during the experiment.

Name any **two** products of the oxidation reaction.

What type of catalysis is involved in this reaction? (12)

Explain **one** way in which the presence of the platinum catalyst speeds up the oxidation of the hot methanol.

Explain how a catalyst poison interferes with this type of catalysis. (9)

Give another example of a reaction which involves the same type of catalysis, indicating clearly the reactant(s) and the catalyst. (6)

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

(*a*) State *Avogadro's law*. (7)

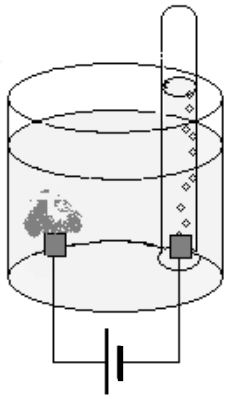
Give **two** assumptions of the kinetic theory of gases. (6)

Give **two** reasons why real gases deviate from ideal gas behaviour. (6)

How many moles of gas are present in a sample containing 1.8×10^{24} atoms of chlorine at s.t.p.? (6)

(*b*) Define oxidation in terms of electron transfer. (4)

The electrolysis, using inert electrodes, of aqueous potassium iodide, **KI**, to which a few drops of phenolphthalein indicator have been added, is shown in the diagram.



(*i*) Name a suitable material for the electrodes. (3)

(*ii*) Write balanced half equations for the reactions that take place at the electrodes. (12)

(*iii*) Explain the colour change observed at the positive electrode (anode). (6)

(*c*) In 1922, Francis Aston, pictured right, was awarded the Nobel Prize in chemistry for detecting the existence of isotopes using the first mass spectrometer.

(*i*) What are isotopes? (7)

(*ii*) What is the principle of the mass spectrometer? (9)

(*iii*) Calculate, to two decimal places, the relative atomic mass of a sample of neon shown by mass spectrometer to be composed of 90.50% of neon–20 and 9.50% of neon–22. (9)

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

(*a*) Ammonia is formed in the Haber process according to the following balanced equation.

$$3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

The table shows the percentages of ammonia present at equilibrium under different conditions of temperature *T* and pressure *P* when hydrogen and nitrogen gases were mixed in a 3:1 molar ratio.

P/atm \ *T*/K	573	673	773
10	15	4	1
100	51	25	10
200	63	36	18
1000	92	80	58

(*i*) Find from the table the conditions of temperature and pressure at which the highest yield of ammonia is obtained. (4)

(*ii*) Deduce from the data whether this reaction is exothermic or endothermic. Explain your reasoning. (6)

(*iii*) Identify **one** industrial problem associated with the use of high pressures. (3)

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

(*v*) State the effect on the value of K_c of using a catalyst. Justify your answer. (6)

(*b*) (*i*) Use a dot and cross diagram to show the bonding in an ammonia, NH_3, molecule. (7)

(*ii*) Use electron pair repulsion theory to determine the shape of the ammonia molecule. Explain clearly why the bond angle in ammonia is only 107°. (9)

(*iii*) Hydrogen bonding occurs between ammonia molecules. What are *hydrogen bonds*? Draw a diagram illustrating hydrogen bonding in ammonia. (9)

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

A

(*i*) Why can very electropositive metals such as sodium only be extracted from their ores by electrolysis? (4)

(*ii*) Explain why the electrolyte used in the Downs cell is molten.
What is the purpose of the calcium chloride used in the process? (6)

(*iii*) Write a balanced equation for overall reaction in the Downs cell.
Explain how the products are prevented from recombining after they have been formed by electrolysis.
Give **one** commercial use for each product. (15)

or

B

Write balanced chemical equations showing

(*i*) the formation of ozone in the stratosphere,

(*ii*) the photodissociation of ozone. (10)

CFCs are a group of substances known to have caused damage to the ozone layer.

(*iii*) State two effects of damage to the ozone layer.

(*iv*) Give one former major use of CFCs.

(*v*) Give an example of a CFC.

(*vi*) Identify the group of compounds now used as ozone friendly CFC replacements. (15)

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