Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2011

CHEMISTRY – HIGHER LEVEL

TUESDAY, 21 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).

The information below should be used in your calculations.

Relative atomic masses: H = 1, O = 16, Na = 23, Mg = 24, S = 32, Cl = 35.5

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

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

Avogadro constant = 6.0×10^{23} mol^{-1}

The use of the Formulae and Tables booklet approved for use in the State Examinations is permitted. A copy may be obtained from the examination superintendent.

Section A

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

1. A chemist determined the concentration of a bleach solution containing **NaClO** by volumetric analysis. A 25.0 cm^3 sample of the bleach was first diluted to exactly 500 cm^3.

A pipette was used to measure a 25.0 cm^3 volume of the diluted bleach and to transfer it into a conical flask. Solutions of potassium iodide, **KI**, and sulfuric acid were added.
The following reaction took place in the conical flask.

$$ClO^- + 2I^- + 2H^+ \rightarrow Cl^- + I_2 + H_2O$$

(*a*) Describe how the 25.0 cm^3 sample of the original bleach solution was diluted to exactly 500 cm^3. (12)

(*b*) What colour developed when the potassium iodide and the sulfuric acid reacted with the diluted bleach in the conical flask? (3)
Give **two** reasons why **excess** potassium iodide was used. (6)

The solution in the conical flask was next titrated with a 0.10 M solution of sodium thiosulfate ($Na_2S_2O_3$).
The average volume of sodium thiosulfate required, when the procedure was repeated a number of times, was 16.1 cm^3.
The balanced equation for the titration reaction was:

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

(*c*) What was the purpose of standing the conical flask on a white tile during the titrations? (3)

(*d*) Name the indicator used in the titrations and state the colour change observed at the end point. (6)

(*e*) Calculate the concentration of **NaClO** in moles per litre in
(*i*) the diluted bleach,
(*ii*) the original bleach. (12)

(*f*) What was the concentration of **NaClO** in the original bleach
(*i*) in grams per litre,
(*ii*) as a % (w/v)? (8)

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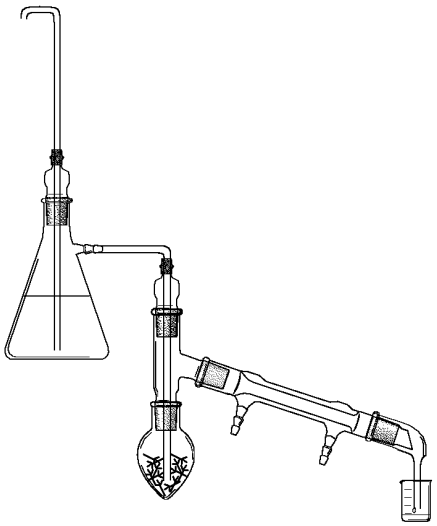
2. (*a*) Reflux is a widely used technique in organic chemistry.

Identify an experiment from your course where you refluxed a mixture.
Draw a <u>fully labelled</u> diagram of the reflux apparatus used in this experiment.

What happened to the liquid in the flask during reflux?
How did refluxing this mixture help bring the reaction to completion? (30)

(*b*) The diagram shows an apparatus suitable for steam distillation.



(*i*) What natural product did you extract in the school laboratory using steam distillation?

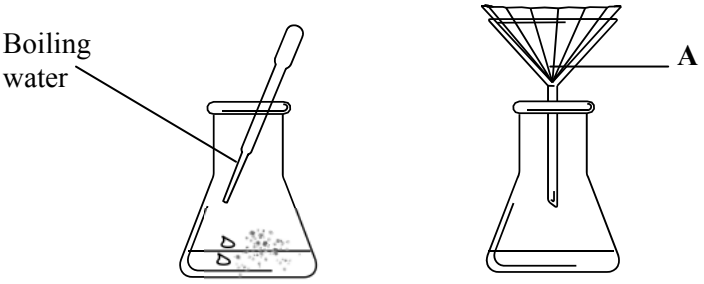
(*ii*) What was the appearance of the material collected during the steam distillation?

(*iii*) What substance distilled across along with the natural product?

(*iv*) Identify **one** safety feature of the apparatus drawn. Explain how this feature contributes to the safe use of the apparatus. (20)

3. Organic solids are frequently purified by recrystallization.
An impure sample of benzoic acid contained small quantities of the two solids: salt (**NaCl**, white and soluble) and charcoal (**C**, black and insoluble).

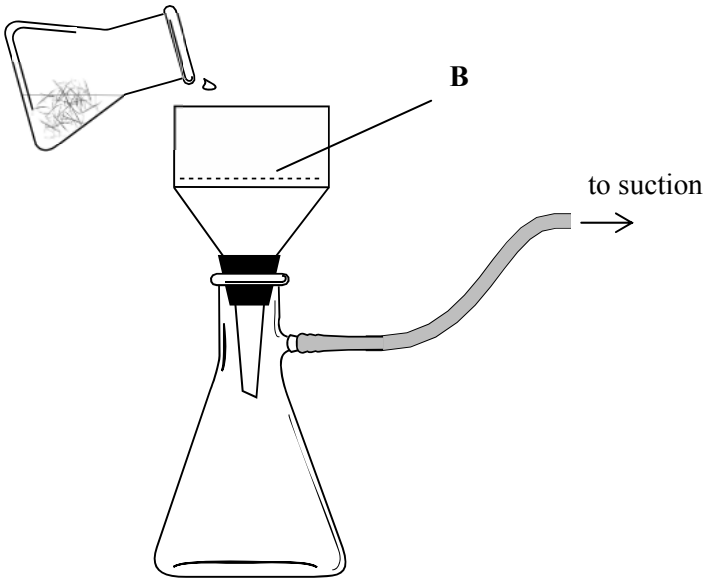
The diagrams illustrate the five main stages in the recrystallization of the impure benzoic acid from water.



Stage 1
Dissolving

Stage 2
Hot filtration

Stage 3
Crystallisation



Stage 4
Filtration

Stage 5
Drying

(*a*) What precaution should have been taken at Stage 1 to ensure the maximum yield of pure benzoic acid crystals at Stage 5? (5)

(*b*) What solid was collected (*i*) at **A**, (*ii*) at **B**? (6)

(*c*) Explain what should have been done at Stage 3 to ensure the maximum yield at Stage 5. (6)

(*d*) Comparing the solubilities of benzoic acid and salt (**NaCl**) in hot and in cold water, explain how benzoic acid is separated from the salt in this procedure. (6)

(*e*) Describe how the benzoic acid was dried at Stage 5. (3)

(*f*) Describe with the aid of a labelled diagram how the melting points of the impure benzoic acid and of the recrystallized, dried benzoic acid could be measured.

How would you have expected the melting point values of the two samples to differ? (18)

(*g*) Give **one** common use of benzoic acid or of its salts. (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*) Give **two** properties of cathode rays.

(*b*) State *Avogadro's law*.

(*c*) Give **two** possible shapes for a covalent molecule of general formula $\mathbf{AB_2}$.

(*d*) Define *the mole,* the SI unit of chemical amount.

(*e*) When 4.10 g of hydrated magnesium sulfate, $\mathbf{MgSO_4.xH_2O}$, were heated strongly, 2.00 g of anhydrous magnesium sulfate were obtained.
Calculate the value of **x**, the degree of hydration of the crystals.

(*f*) Complete and balance the equation for the chemical reaction that occurs when a piece of aluminium is placed in a solution of copper(II) ions: $\mathbf{Cu^{2+} + Al \rightarrow}$

(*g*) Give **two** methods for removing all of the hardness in a water sample.

(*h*) Define *the activation energy* of a chemical reaction.

(*i*) What is a *homologous series* of organic compounds?

(*j*) What is the principle involved in the separation of a mixture by chromatography?

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

A How do metallic crystals conduct electricity?

or

B What is meant by the *greenhouse factor* of a gas in the atmosphere?

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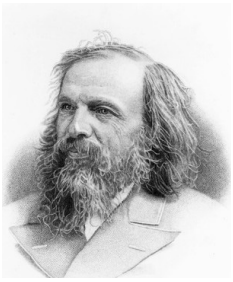
5. (*a*) Define (*i*) *atomic number*, (*ii*) *relative atomic mass*. (11)



(*b*) Sixty-two elements were known when Mendeleev, pictured on the right, published his periodic table of the elements in 1869.

What was the basis (periodic law) used by Mendeleev in arranging the elements in his periodic table?

Why did Mendeleev leave spaces in his periodic table, e.g. where the element germanium occurs in the modern periodic table?

In a few instances Mendeleev reversed the order of elements required by his periodic law. For example, he placed the element tellurium before the element iodine. Explain why he did this.(12)

(*c*) One of the most useful features of the periodic table of the elements is that it allows trends in the properties of the elements to be compared.

Explain why (*i*) the alkali metals are all reactive, (*ii*) the reactivity of the alkali metals increases down the group. (9)

(*d*) The arrangement of elements in the modern periodic table is now known to be consistent with their electrons filling into atomic orbitals of increasing energy.

(*i*) Define *atomic orbital*.

(*ii*) Write the electron configuration (*s*, *p*, etc.) of the element manganese (**Mn**).

(*iii*) What do the electron configurations of the series of elements from scandium to zinc have in common? (18)

6. Over 20% of the crude oil refined at Whitegate in Cork Harbour in 2010 was imported from Libya. Libyan crude oil is particularly valued because of its rich light gasoline and naphtha content. Social unrest in the Middle East early in 2011 has again highlighted Ireland's heavy dependence on oil as an energy source. Unstable supplies, the high cost of importing quality crude oil, and environmental issues focus attention on alternative energy sources including fuels, other than fossil fuels, e.g. hydrogen, and diesel derived from vegetable oil.

(*a*) What is the nature of the chemicals that make up the bulk of crude oil? (5)

(*b*) Unprocessed crude oil, obtained by drilling on land or at sea, is not generally useful. Describe with the aid of a labelled diagram how crude oil is separated into useful substances in an oil refinery.
Give the major use for the light gasoline and naphtha fractions of crude oil. (15)

(*c*) What is *catalytic cracking*? Why is it carried out in oil refining? (9)

(*d*) Hydrogen gas can be obtained industrially by the reaction between natural gas and water in the form of steam (steam reforming).

(*i*) Describe another method by which large quantities of hydrogen can be obtained from water.

(*ii*) State **one** disadvantage of using hydrogen as a fuel. (9)

(*e*) Steam reforming takes place according to the following balanced equation:

$$\mathbf{CH_{4\,(g)} + H_2O_{\,(g)} \rightarrow CO_{\,(g)} + 3H_{2\,(g)}}$$

Calculate the heat of this steam reforming reaction given that the heats of formation of methane, steam and carbon monoxide are –74.6, –242 and –111 kJ mol^{-1} respectively. (12)

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7. Sulfuric acid is a strong dibasic acid. The formula **HA** represents a weak monobasic acid.

(*a*) How do strong acids differ from weak acids in their behaviour in water according to (*i*) the Arrhenius theory, (*ii*) the Brønsted-Lowry theory? (12)

(*b*) What is the conjugate base of (*i*) sulfuric acid, (*ii*) the weak acid **HA**?
Which of these conjugate bases is the stronger? Explain. (12)

(*c*) Explain, by giving a balanced equation for its dissociation in water, that the conjugate base of sulfuric acid is itself an acid. (6)

(*d*) Define pH. (6)

Calculate the pH of a 0.2 M solution of a weak acid, **HA**, the value of whose acid dissociation constant, $\boldsymbol{K_a}$, is 6.3×10^{-5} mol l^{-1}.
What is the concentration of a sulfuric acid solution that has the same pH? (14)

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8. Answer the questions below about methane (a saturated hydrocarbon), ethene (an unsaturated hydrocarbon) and benzene (an aromatic hydrocarbon).

(*a*) Describe the mechanism of the monochlorination of methane. (12)

State **three** pieces of experimental evidence for the mechanism you have given.
Explain how each piece of evidence supports the mechanism you have described. (18)

(*b*) Ethene can be made by passing ethanol vapour over hot aluminium oxide.

(*i*) Name the type of organic reaction involved in this conversion.

(*ii*) List the bonds broken and the bonds formed in this reaction. (12)

(*c*) Describe the bonding in benzene. (8)

9. (*a*) Hydrogen iodide, when placed in a sealed vessel at 700 K, decomposes to form hydrogen gas and iodine vapour. An equilibrium, described by the following balanced equation, is established.

$$\mathbf{2HI_{(g)} \rightleftharpoons H_{2\,(g)} + I_{2\,(g)} \qquad \Delta H = 10.4\ kJ}$$

Write the equilibrium constant (K_c) expression for this reaction. (5)

Calculate the equilibrium concentration of hydrogen gas when 5 moles of hydrogen iodide decompose in a 12 litre vessel at 700 K. The value of K_c at this temperature is 0.0185. (18)

(*b*) A pink solution was formed when crystalline cobalt(II) chloride, $\mathbf{CoCl_2.6H_2O}$, was dissolved in deionised water and the following equilibrium was established.

$$\underset{\text{pink}}{\mathbf{Co(H_2O)_6^{2+}}} + \mathbf{4Cl^-} \rightleftharpoons \underset{\text{blue}}{\mathbf{CoCl_4^{2-}}} + \mathbf{6H_2O}$$

Concentrated hydrochloric acid was added carefully, dropwise, until the colour of the solution changed to lilac (pale violet). A small volume of the lilac (pale violet) solution was placed in each of four test tubes labelled **A** – **D**. Test tube **D** was kept as a reference.

Explain (*i*) the lilac (pale violet) colour in test tubes **A** – **D**,

(*ii*) the colour that appeared when a few drops of water were added to test tube **A**,

(*iii*) the colour that appeared when a few drops of concentrated hydrochloric acid were added to test tube **B**. (18)

When test tube **C** was placed in a beaker containing ice and water the solution in the test tube became pink.
Is the forward reaction exothermic or endothermic? Justify your answer. (9)

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

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

There is a slow exothermic reaction between hydrogen and oxygen gases mixed in a 2:1 ratio at room temperature but the reaction becomes violently rapid if powdered platinum catalyst is added.
Suggest the type of catalysis responsible for the increased rate of reaction.
Describe the mechanism by which the powdered platinum increases the rate of reaction. (12)
Draw a clearly labelled reaction profile diagram for the reaction with and without the catalyst. (8)

(*b*) Ethanol and carbon dioxide are obtained from glucose, $\mathbf{C_6H_{12}O_6}$, by the action of the enzyme zymase which occurs in yeast. Write a balanced chemical equation for this fermentation reaction. (7)

When a person drinks ethanol it is broken down in the liver at a fairly consistent average rate of 5.3 g/hour in a woman and 7.3 g/hour in a man.
Name the primary metabolite of ethanol in the human liver. (3)

A woman drank two 175 ml standard glasses of wine labelled 12.5% (v/v).

(*i*) Calculate how long it took her liver to process all of the ethanol in the wine. Take the density of ethanol as 0.8 g/ml.

(*ii*) Assuming that at no point was more than 90% of the consumed ethanol distributed in the woman's body fluids, state her maximum blood ethanol concentration in terms of mg ethanol/100 ml blood. Take the woman's total body fluid volume as 28 litres and assume that the ethanol was distributed uniformly. (15)

(*c*) What are *isotopes*? (5)

Define (*i*) *radioactivity*, (*ii*) *radioisotope*. (8)

Carbon–14 decays by beta particle emission. Write a balanced equation to describe beta-decay of the carbon–14 nucleus. (6)

The world's oldest shoe, found in a cave in Armenia, is pictured on the right.
In June 2010, having been radiocarbon dated, it was reported to be 5500 years old.
Explain why the carbon–12 to carbon–14 isotope ratio in the shoe leather changed over the 5500 years since the shoe was made. (6)

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

(*a*) What is meant by the *biochemical oxygen demand* (BOD) of a water sample? (7)

The BOD of a raw sewage sample was 350 ppm and the BOD of the same sample after treatment was about 25 ppm.

(*i*) Describe how the BOD was reduced by about 30% in primary sewage treatment. (9)

(*ii*) Explain the processes by which the BOD was further reduced in secondary sewage treatment. (9)

(*b*) (*i*) Distinguish between *ionic bonding* and *polar covalent bonding*. (7)

(*ii*) Why do ionic substances conduct electricity when molten or dissolved in water but not in the solid state? (6)

(*iii*) Ammonia is polar covalent and is water-soluble.

Show that the ammonia molecule ($\mathbf{NH_3}$) has polar covalent bonding.

Describe the processes involved when ammonia dissolves in water. (12)

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

A

Roy Plunkett, pictured on the right, produced the polymer poly(tetrafluoroethene) (Teflon) accidentally in 1938 when he was researching refrigerants.

(*i*) Identify the monomer used to manufacture poly(tetrafluoroethene) (Teflon). (4)

(*ii*) What type of polymerisation reaction occurs in the manufacture of poly(tetrafluoroethene) (Teflon)? (3)

(*iii*) Draw two repeating units of the Teflon polymer. (6)

(*iv*) Give **two** properties of poly(tetrafluoroethene) (Teflon). In the case of each property you have stated, give a major use of the polymer that makes use of that property. (12)

or

B

Outline the chemical processes that give rise to the occurrence of ozone gas in the stratosphere. Why is ozone gas not produced in this way in the lower atmosphere? (10)

The destruction of the ozone layer is a matter of environmental concern. A non-metal oxide and chlorine atoms from CFCs are considered to be mainly responsible for the destruction of ozone.

(*i*) What are CFC molecules? (3)

(*ii*) Why do CFC molecules have long residence times in the lower atmosphere? (3)

(*iii*) Give a major use of CFCs before their production was restricted in 1987. (3)

(*iv*) Name the non-metallic oxide that is associated with ozone destruction in the stratosphere. (3)
Give a source of this oxide. (3)

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