Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2015

CHEMISTRY – HIGHER LEVEL

TUESDAY, 16 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).

The information below should be used in your calculations.

Relative atomic masses (rounded): H = 1.0, C = 12, N = 14, O = 16, Na = 23, Mg = 24, Si = 28, S = 32, Cl = 35.5, Cu = 63.5, I = 127

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

Molar volume at room temperature and pressure = 24.0 litres

Universal gas constant = 8.3 J K^{-1} 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. Sodium thiosulfate is a reducing agent that reacts with iodine according to the following balanced equation.

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

To determine the concentration of a sodium thiosulfate solution, a student titrated it against 25.0 cm^3 portions of a standard iodine solution.

(*a*) Explain how iodine, a non-polar substance of very low water solubility, is brought into aqueous solution. (6)

(*b*) The iodine solution was made up in a 500 cm^3 volumetric flask. Describe the procedure for measuring 25.0 cm^3 of this solution into a conical flask. (12)

(*c*) Name a suitable indicator for this titration.

At what stage is the indicator added?

State the colour change at the end point in the presence of the indicator. (9)

(*d*) Given that there were 6.35 g of iodine ($\mathbf{I_2}$) in 500 cm^3 of the iodine solution, calculate

(*i*) the number of moles of iodine in each 25.0 cm^3 portion,

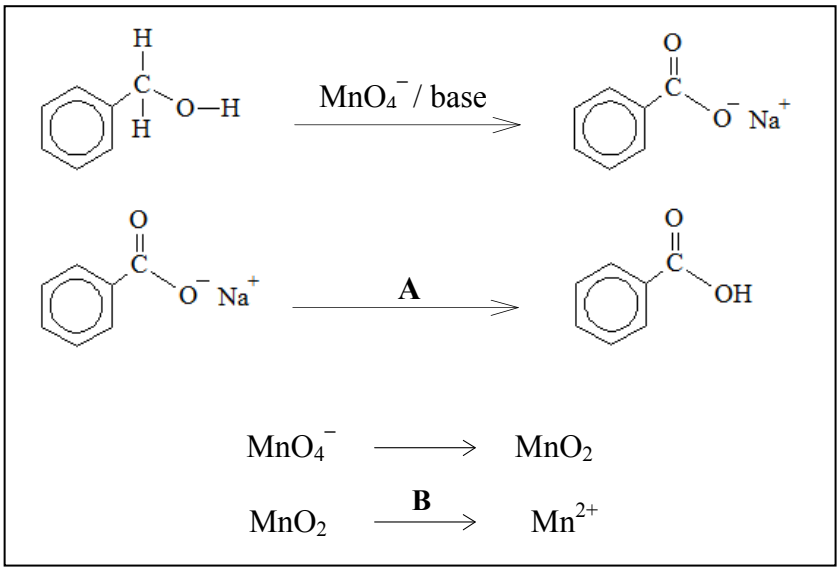
(*ii*) the number of moles of sodium thiosulfate required to reduce this quantity of iodine,

(*iii*) the concentration of the sodium thiosulfate solution in moles per litre, 17.85 cm^3 of which were required to reduce 25.0 cm^3 of the iodine solution,

(*iv*) the concentration of the sodium thiosulfate solution in grams per litre of its crystals ($\mathbf{Na_2S_2O_3.5H_2O}$). (18)

(*e*) Explain why the use of *distilled* water instead of *deionised* water throughout this experiment would be likely to ensure a more accurate result. (5)

2. One molecule of phenylmethanol (benzyl alcohol) can be oxidised to one molecule of benzoic acid by potassium manganate(VII) in basic conditions as shown in the reaction scheme below.



(*a*) Describe the appearance of phenylmethanol at room temperature. (5)

(*b*) State the colour change when phenylmethanol was heated gently with potassium manganate(VII) solution to which sodium carbonate had been added.

Identify **A** and **B** in the reaction scheme that were added to allow separation of the benzoic acid from the other substances after the oxidation was complete.

What changes were observed in the reaction vessel on addition of these two chemicals and as cooling occurred?

State the changes in the oxidation number of manganese during the experiment. (24)

(*c*) After isolation by filtration, the benzoic acid crystals were purified by recrystallisation.

State one way of maximising the yield of the recrystallisation process.

The melting point range of the benzoic acid crystals before recrystallisation was 112 – 118 °C.

How would recrystallisation have affected the melting point range? (9)

(*d*) A student oxidised 2.7 cm^3 of phenylmethanol (density 1.04 g cm^{-3}) and obtained 1.83 g of benzoic acid after recrystallisation. Assuming that phenylmethanol was the limiting reactant, calculate the percentage yield of benzoic acid. (12)

3. The quality of water samples from swimming-pools **A**, **B**, **C** and **D** was assessed. The results of the tests carried out are summarised in the table.

Sample / Pool	**A**	**B**	**C**	**D**
Suspended solids (p.p.m.)	350	500	650	420
Dissolved solids (p.p.m.)	1280	1400	1290	1360
Total hardness (p.p.m. $CaCO_3$)	215	210	220	212
Free chlorine (p.p.m.)	0.1	1.2	2.5	7.0
pH	7.2	7.3	7.2	7.3
Suitable for swimming?	No	Yes	Yes	No

(*a*) Describe how the concentration of suspended solids in sample **A** could have been measured. (12)

(*b*) Calculate the mass in grams of dissolved solids in 250 cm^3 of sample **B**. (6)

(*c*) Hardness in swimming-pool water can contribute to cloudiness.

What solution was titrated against a known volume of sample **C** to measure its total hardness?

When some of sample **C** was boiled, filtered, and re-analysed for hardness, the result was 175 p.p.m. $CaCO_3$.

Suggest a reason why the second result was significantly lower than the first. (9)

(*d*) Identify a reagent (or reagents) used to detect free chlorine in a water sample.

Describe how a comparator *or* a colorimeter could have been used to estimate the concentration of free chlorine in sample **D**. (15)

(*e*) Which of the test results led to pools **A** and **D** being considered unsuitable for swimming?

What problem might arise for swimmers

(*i*) in pool **A**,

(*ii*) in pool **D**? (8)

Section B

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

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

(*a*) How many (*i*) electrons, (*ii*) neutrons, has the aluminium ion, $^{27}_{13}\mathbf{Al}^{3+}$?

(*b*) Explain why relative atomic masses are rarely whole numbers.

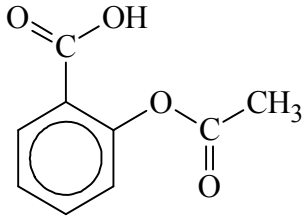
(*c*) What change takes place in the nucleus of an atom when beta decay occurs?

(*d*) Account for the difference in the shapes of the boron trifluoride ($\mathbf{BF_3}$) molecule and the ammonia ($\mathbf{NH_3}$) molecule.

(*e*) When 19.05 g of copper reacted with nitrogen, 20.45 g of copper nitride were produced.
Deduce the empirical formula of copper nitride.

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

(*g*) Copy the structure of the aspirin molecule shown into your answer book.



(*i*) Draw a **circle** around the carboxylic acid group.

(*ii*) Draw a **rectangle** around the carbonyl part of the ester group.

(*h*) In the periodic table, identify an element

(*i*) in the same period as magnesium but with larger atoms,

(*ii*) in the same group as magnesium but with smaller atoms.

(*i*) What is the purpose of tertiary sewage treatment?

(*j*) Calculate the number of moles of nitrogen gas at a pressure of 1.85×10^5 Pa and a temperature of 293 K in the 6.50×10^{-5} m^3 volume inside a new tennis ball. Give your answer correct to one significant figure.

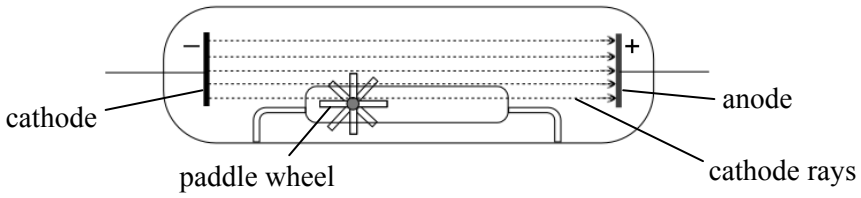
(*k*) Answer part **A** *or* part **B**.

A State two ways by which nitrogen is fixed in nature.

or

B The first, third and fourth of the five stages involved in recycling polystyrene are sorting, washing and drying respectively.
What are the second and fifth stages?

5. (*a*) During the 1870s Crookes investigated cathode rays using vacuum tubes like that shown below.



(*i*) Give one way of detecting the presence of cathode rays in a vacuum tube.

(*ii*) Name the scientist who around 1897 identified cathode rays as subatomic particles and, using a vacuum tube, measured their charge-to-mass ratio.

What name was given to the subatomic particle he identified? (9)

(*b*) Name one of the three scientists who shared the 1903 Nobel prize in Physics for their pioneering work on radioactivity which provided evidence for subatomic particles. (3)

(*c*) Rutherford concluded around 1910 that the electrons in an atom are located in a large, almost empty space surrounding a tiny, dense, positive nucleus.

State three observations made by Rutherford's team when they bombarded gold foil with alpha-particles.

Explain how Rutherford deduced from these observations that the nucleus is

(*i*) positive,

(*ii*) small *and* dense. (15)

(*d*) In 1913 Bohr proposed that electrons in an atom occupy certain stable states or *energy levels*.

Explain how the line emission spectrum of hydrogen arises and provides evidence for the existence of energy levels. (12)

(*e*) The colours produced by fireworks provide evidence for energy levels in atoms of other elements.

Suggest an element that gives a blue-green colour to a fireworks display. (3)

(*f*) Bohr's theory was later modified and we now understand that electrons in an atom occupy *atomic orbitals*.

Write the *s*, *p* electron configuration of a calcium atom in its ground state.

Give one significant difference between an electron in the 2*s* orbital and an electron in the 3*s* orbital of a calcium atom. (8)

6. (*a*) Each fraction separated in the refining of crude oil is a mixture of hydrocarbons. Identify a property of a hydrocarbon that results in its presence in a particular fraction. (5)

(*b*) (*i*) Name the fraction, obtained from crude oil, that is used as fuel for jet aircraft.

(*ii*) What process is used to convert molecules in this fraction to smaller molecules that are in greater demand? (6)

(*c*) What are the two reference hydrocarbons used to assign octane numbers to fuels? (6)

(*d*) Give two advantages of adding oxygenates, such as ethanol, to petrol. (6)

(*e*) Ethanol can also be used as a fuel.

Calculate the heat of formation of ethanol given that the heat of combustion of ethanol is –1370.7 kJ mol^{-1} and that the heats of formation of carbon dioxide and water are –393.5 and –285.8 kJ mol^{-1} respectively. (12)

(*f*) The NASA Space Shuttle programme flew 135 missions between 1981 and 2011 using hydrogen as the fuel.

(*i*) Give two properties of hydrogen that made it the fuel of choice for the Space Shuttle.

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

(*iii*) Give two ways that hydrogen gas is produced industrially. (15)

7. (*a*) What is a *catalyst*? (5)

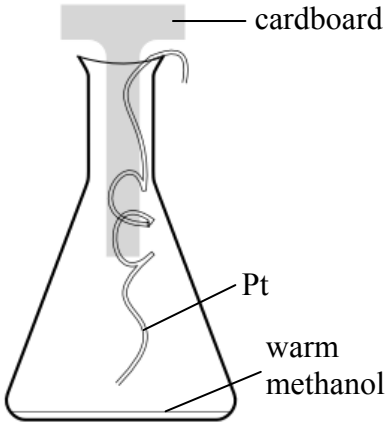
(*b*) Explain how the type of bonding in the reactants influences the rate of a chemical reaction in aqueous solution.

How could you reduce the rate of a reaction that takes place in solution? (9)

The diagram shows the oxidation of methanol using platinum wire as catalyst.

(*c*) State one observation made during this experiment.

Identify two major products of the oxidation. (9)



(*d*) What term is usually used to describe the attachment of liquid or gaseous molecules to a solid surface?

Explain how this type of interaction between the methanol and the platinum catalyst affects the rate of oxidation.

Explain how a catalyst poison like sulfur interferes with a catalyst. (9)

(*e*) Explain the term *activation energy of a reaction*.

Sketch a reaction profile diagram for an exothermic reaction labelling the axes and marking clearly on your diagram the heat of reaction (ΔH) and the activation energy for the reaction (E_A). (18)

8. Study the reaction scheme below and answer the questions that follow.

(*a*) Give the IUPAC names for **A**, **B** and **C**. (8)

(*b*) Name the addition polymer formed from compound **A**. (3)

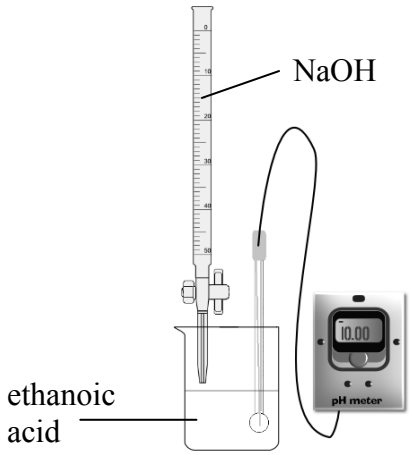
(*c*) Identify the bonds broken and the bonds formed in conversion **Y**. (9)

(*d*) An isomer of compound **B** can be synthesised from an aldehyde.
Name the isomer of compound **B** and the aldehyde and draw their full structural formulae.
How can the aldehyde be converted to the isomer of compound **B**? (18)

(*e*) The boiling points of compounds **A**, **B** and **C** are –48, 56 and 82 °C, but not necessarily in that order.
For each compound, identify its boiling point, justifying your answer in terms of intermolecular forces. (12)

9. (*a*) Define *acid* according to the theory of
(*i*) Arrhenius,
(*ii*) Brønsted-Lowry. (6)

(*b*) Define pH.
State one limitation of the pH scale. (9)



A sodium hydroxide solution was titrated with a solution of ethanoic acid using the apparatus shown on the right. A number of pH readings, together with the corresponding volumes of sodium hydroxide solution added, are shown in the table.

Volume NaOH (cm^3)	pH
0.0	3.3
2.0	4.1
5.0	4.5
10.0	4.8
15.0	5.1
17.5	5.6
19.0	6.2
19.5	6.6
19.8	7.0
20.0	8.9
20.2	10.7
20.5	11.1
22.0	11.6
25.5	12.1
30.0	12.3
40.0	12.4

(*c*) Graph the pH curve for the titration. (15)

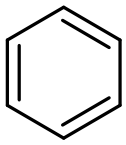
(*d*) (*i*) Calculate the initial concentration of ethanoic acid ($K_a = 1.8 \times 10^{-5}$) in the beaker.
(*ii*) Make use of your graph to deduce the volume of sodium hydroxide solution required for neutralisation. (12)

(*e*) What indicator could be used to detect the end point in this titration?
Refer to your pH curve to justify your answer. (8)

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

(*a*) Distinguish between *saturated* and *unsaturated* hydrocarbons.
Describe how you would test a given hydrocarbon for unsaturation. (13)

In 1865 August Kekulé proposed the structure for benzene shown on the right.
How many pi-electrons are there in benzene?
Explain whether or not the Kekulé structure correctly describes
(*i*) the number,
(*ii*) the distribution, of the pi-electrons in benzene.
Give one piece of experimental evidence in support of your explanation to part (*ii*). (12)



(*b*) Electrolysis is used to purify copper for applications in the electronics industry.

(*i*) Explain with the aid of a clearly-labelled diagram how impure copper is purified by electrolysis. (15)

(*ii*) Write balanced equations for the reactions that take place at the electrodes. (6)

(*iii*) What happens to impurities in the copper during this electrolysis? (4)

(*c*) Silicon dioxide reacts vigorously with magnesium powder to form magnesium silicide, a dark blue solid. When magnesium silicide dissolves in hydrochloric acid, the silane gas produced ignites spontaneously when it comes into contact with oxygen in the air. The balanced equations for these reactions are given below.

$$\mathbf{SiO_2 + 4Mg \rightarrow Mg_2Si + 2MgO}$$

$$\mathbf{Mg_2Si + 4HCl \rightarrow SiH_4 + 2MgCl_2}$$

$$\mathbf{SiH_4 + 2O_2 \rightarrow SiO_2 + 2H_2O}$$

(*i*) What is meant by *a mole* of a substance? (6)

(*ii*) How many moles of magnesium react with silicon dioxide to produce 7.6 g of magnesium silicide? (6)

(*iii*) Calculate the number of moles of hydrogen chloride required to react with 7.6 g of magnesium silicide.
What mass of magnesium chloride is produced? (9)

(*iv*) What volume of oxygen gas, measured at room temperature and pressure, is required for the complete combustion of the silane produced from 7.6 g of magnesium silicide? (4)

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

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

Why is there an increase in electronegativity value moving from gallium to germanium in the periodic table? (6)

Mendeleev predicted the properties of the elements gallium and germanium years before either of them was discovered. Explain the basis for his predictions. (6)

Write the molecular formula for the simplest compound formed between germanium(IV) and hydrogen.

Would you expect this compound to be water soluble? Justify your answer. (7)

(*b*) Gas **A** is in equilibrium with gases **B** and **C** according to the following equation.

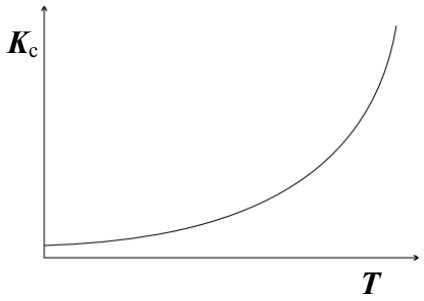
$$\mathbf{A}_{(g)} \rightleftharpoons \mathbf{B}_{(g)} + \mathbf{C}_{(g)}$$

The equilibrium constant ($\boldsymbol{K}_c$) value at 15 °C for the dissociation reaction is 4.0.

A rigid 10 litre container was filled with 30 moles of gas **A** and stored at 15 °C.

Calculate the number of gaseous moles at equilibrium in the container. (13)

The graph shows the relationship between temperature (***T***) and $\boldsymbol{K}_c$ for this equilibrium.



Deduce whether the dissociation of gas **A** is exothermic or endothermic.
Explain your reasoning. (6)

Explain how an increase in the storage temperature would affect the pressure of the equilibrium mixture. (6)

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

A

'Ireland is facing significant challenges in meeting its EU future emissions targets for greenhouse gases under the EU Climate and Energy package for 2020.'
(www.epa.ie)

(*i*) Explain the underlined term. (4)

(*ii*) State one global climate change implication of failure to control greenhouse gas emissions. (3)

(*iii*) Arrange water vapour, methane, carbon dioxide and a typical chlorofluorocarbon, in order of their increasing greenhouse factors.
Which of these gases contributes most to the greenhouse effect?
Describe one way that chlorofluorocarbons are broken down in the stratosphere. (12)

(*iv*) Suggest two ways by which Ireland could reduce its emissions of greenhouse gases. (6)

or

B

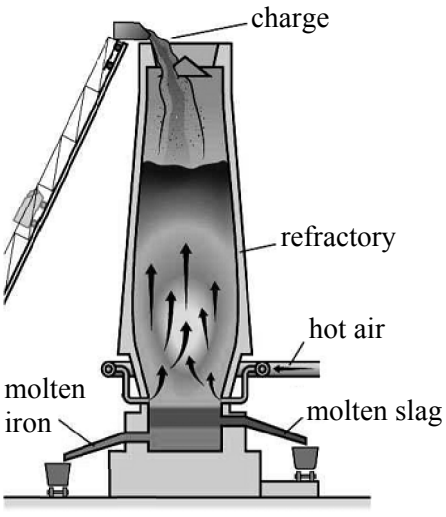
Iron metal is extracted in a blast furnace by the reduction of iron oxides in iron ore. The ore is present in the charge added at the top of the furnace while hot air is pumped in at the bottom as shown.

(*i*) Name the two other substances present in the charge. (4)

(*ii*) Write a balanced equation for the reduction of iron(III) oxide to iron in the furnace. (6)

(*iii*) Use balanced equations to show how a major impurity in the iron ore reacts to form slag.
Give a use for the slag. (9)

(*iv*) Give one harmful effect that iron extraction by blast furnace could have on the environment.
How could this effect be minimised? (6)



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