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LEAVING CERTIFICATE EXAMINATION, 2002

CHEMISTRY - HIGHER LEVEL

TUESDAY, 18 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, Na = 23, Cl = 35.5

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

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

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

Section A

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

1. Vinegar is a solution of ethanoic acid (acetic acid). Some bottles of vinegar are labelled "*White Wine Vinegar*".

(a) What compound in white wine is converted to ethanoic acid in vinegar?
What type of chemical process converts this compound to ethanoic acid? (8)

The concentration of ethanoic acid in vinegar was measured as follows:
A 50 cm^3 sample of vinegar was diluted to 500 cm^3 using deionised water. The diluted solution was titrated against 25 cm^3 portions of a standard 0.12 M sodium hydroxide solution, using a suitable indicator.

(b) Describe the procedure for accurately measuring the 50 cm^3 sample of vinegar and diluting it to 500 cm^3. (12)

(c) Name the piece of equipment that should be used to measure the ethanoic acid solution during the titration. State the procedure for washing and filling this piece of equipment in preparation for the titration. Name a suitable indicator for this titration. (15)

The titration reaction is

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

After carrying out a number of accurate titrations of the diluted solution of ethanoic acid against the 25 cm^3 portions of the standard 0.12 M sodium hydroxide solution, the mean titration figure was found to be 20.5 cm^3.

(d) Calculate the concentration of ethanoic acid in the diluted vinegar solution in moles per litre and hence calculate the concentration of ethanoic acid in the original sample of vinegar.
Express this concentration in terms of % (w/v). (15)

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2. Soap is produced by the hydrolysis of vegetable and animal fats.

(a) What is the principal chemical difference between vegetable and animal fats? (5)

A sample of soap was prepared in a school laboratory as follows:
Approximately 3 g of lard (animal fat), 2 g of sodium hydroxide pellets (an excess), and 25 cm^3 of ethanol were placed in a round-bottomed flask. A condenser was fitted to the flask and the mixture was refluxed gently for 20 minutes (Diagram 1).

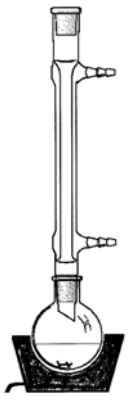

Diagram 1

Following the reflux, the apparatus was allowed to cool slightly and the arrangement of the apparatus was changed so that the ethanol could be removed by distillation (Diagram 2).

The residue from the distillation flask was then dissolved in a minimum of hot water and the solution decanted into 75 cm^3 of brine. The soap was then isolated.

(b) Apart from the lard, sodium hydroxide and ethanol, what else should be added to the reaction flask prior to the reflux?
Why was the mixture refluxed?
Why was the ethanol added? (15)

(c) Why was it desirable to remove the ethanol after the reflux? (9)

(d) Why was a <u>minimum</u> of hot water used to dissolve the residue from the distillation? What is brine? (9)

(e) Describe how the soap could be isolated from the mixture of soap and brine. Give <u>one</u> precaution that helps to ensure that the soap is free of sodium hydroxide. (12)

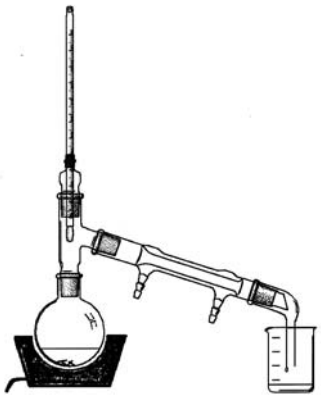

Diagram 2

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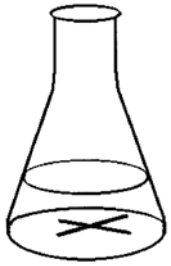
3. To investigate the effect of concentration on a reaction rate, a student measured 100 cm^3 of a 0.10 M solution of sodium thiosulfate into a conical flask, added 10 cm^3 of 1.0 M hydrochloric acid, and then placed the flask on top of a cross on a sheet of white paper as shown in the diagram. The student noted the time (in minutes) taken for the cross to become obscured by the pale yellow precipitate formed in the solution. The reciprocal of the time (1/time) was used as a measure of the initial rate of the reaction.

Samples of the 0.10 M solution of sodium thiosulfate were diluted to make 100 cm^3 portions of 0.08, 0.06, 0.04 and 0.02 M sodium thiosulfate. Each of these was, in turn, reacted with 10 cm^3 of 1.0 M hydrochloric acid as described above. The results obtained are shown in the following table.

Concentration of sodium thiosulfate solution (M)	Time taken for the cross to become obscured (minutes)	1/time (min^{-1}) i.e. Rate
0.10	1.25	0.80
0.08	1.56	0.64
0.06	2.08	0.48
0.04	3.13	0.32
0.02	6.25	0.16



(a) Identify the pale yellow precipitate that obscured the cross on the sheet of paper. (5)

(b) Describe the procedure for preparing the 0.08 M solution of sodium thiosulfate from the 0.10 M solution. (12)

(c) Plot a graph to show the relationship between the initial rate of this reaction (1/time) and the concentration of the sodium thiosulfate solution. What conclusion can be drawn from the graph about the relationship between the rate of reaction and the concentration of the sodium thiosulfate? (18)

(d) Use the graph to determine how long it would have taken for the cross on the sheet of paper to become obscured if the student had used a 0.05 M sodium thiosulfate solution. (9)

(e) Explain why the reciprocal of the time (1/time) may be used as a measure of the initial rate of the reaction. (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) What are *isotopes*?

(b) Write the electronic configuration of a neutral copper atom.

(c) Define *atomic orbital*.

(d) The value of the dissociation constant for ethanoic acid is 1.8×10^{-5} l mol^{-1}.
Calculate the pH of a 0.01 M solution of ethanoic acid.

(e) What is the oxidation number of sulfur in $\mathbf{Na_2S_2O_3}$?

(f) How could you test for the presence of nitrate ions in aqueous solution?

(g) What colour change will occur if concentrated sulfuric acid is added to the following equilibrium mixture? Give a reason for your answer.

$$\mathbf{2CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O}$$

(h) What spectroscopic technique is used to detect heavy metals, e.g. lead, in environmental analysis?

(i) State *Charles's law*.

(j) Draw the structure and give the IUPAC name for $\mathbf{CH_3CHO}$.

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

A Write an equation for the photodissociation of ozone.

B What are the structural differences between low-density and high-density poly(ethene)?

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5. Refer to the data in the Mathematics Tables, pages 44 – 46, in answering this question.

(a) Define *first ionisation energy*. (8)

(b) Account fully for the trends in first ionisation energies of elements across the second period of the periodic table (i.e. Li to Ne). (15)

(c) Account for the trend in first ionisation energies of the elements going down Group II of the periodic table, i.e. the alkaline-earth metals. (6)

The approximate values for the first eight ionisation energies of magnesium are given in the following table.

Ionisation	1st	2nd	3rd	4th	5th	6th	7th	8th
Ionisation energy (kJ mol^{-1})	730	1450	7750	10500	13600	18000	21500	25600

(d) Explain why there is an increase in these ionisation energy values. (9)

(e) Account for the dramatic increase in ionisation energy going from the second to the third ionisation. Between which two ionisations would you expect the next dramatic increase to occur if the data for further ionisation energies of magnesium were examined? Give a reason for your answer. (12)

6. Answer the questions (a) to (e) with reference to the compounds **A**, **B** and **C**.

C_3H_6	C_3H_7OH	CH_3COCH_3
A	**B**	**C**

(a) Which one of the three compounds would you expect to be the least soluble in water? Give a reason for your answer. (8)

(b) Give the IUPAC names of compounds **A** and **C**. Name both isomers of compound **B**. Name a compound that is a structural isomer of **C**. (15)

(c) Classify each of the compounds **A**, **B** and **C** as having one, two or three tetrahedrally bonded carbon atoms. (9)

(d) Compound **C** can be synthesised from compound **A** in two steps, with one of the isomers of **B** as the product of the first step. Name suitable reagents for each of the steps. (12)

(e) Compound **C** is a solvent. Give a common use for this solvent. (6)

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7. Mass spectrometry and gas chromatography are widely used instrumental techniques in chemistry.

(a) Give one application of each of these techniques. (8)

(b) What are the main principles on which each of these techniques is based? (18)

(c) What are the fundamental processes that occur in a mass spectrometer? (15)

(d) HPLC is another chromatographic technique.
What do the letters HPLC stand for? State one application of this technique. (9)

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8. The following hydrocarbons can all be used as fuels.

methane (CH_4) **butane (C_4H_{10})** **2,2,4-trimethylpentane (C_8H_{18})**

(a) Butane is a major component of LPG. What do the letters LPG stand for? (5)
Draw two structural isomers of butane. (6)

(b) Methane is a major component of natural gas.
Why are mercaptans often added to natural gas?
What environmental change or effect is associated with the release of methane to the atmosphere?
Apart from leaking gas pipes, name a major source from which methane is released to the atmosphere. (9)

(c) What structural feature of 2,2,4-trimethylpentane results in it having a high octane rating?
Give one other structural feature which increases the octane number of a hydrocarbon. (6)

(d) Define *heat of combustion* of a compound. (6)

(e) The combustion of butane is described by the following balanced equation.

$$\mathbf{2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(l)}}$$

Calculate the heat of combustion of butane given that the heats of formation of butane, carbon dioxide and water are –125, –394 and –286 kJ mol^{-1}, respectively. (18)

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9. (a) What property of water makes it very useful in the human body as a medium in which chemical reactions occur, and also allows it to become polluted or contaminated very easily in other situations? (5)

The treatment of a water supply for domestic use may involve several stages.

(i) These stages may include *sedimentation*, *flocculation* and *filtration*.
Describe what happens at <u>each</u> of these three stages. (18)

(ii) Various chemicals are often added in other stages of water treatment.
Identify <u>one</u> other stage in water treatment which involves the addition of a chemical to the water.
Name <u>one</u> chemical added during this stage and state why this chemical is added. (9)

(b) (i) Distinguish between the primary and secondary stages of sewage treatment. (12)

(ii) What is the purpose of tertiary treatment? (6)

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

(a) Define *oxidation number*. (4)

(i) Using oxidation numbers, identify which species is being oxidised and which species is being reduced in the following reaction. (12)

$$MnO_4^- + Cl^- + H^+ \rightarrow Mn^{2+} + Cl_2 + H_2O$$

(ii) Hence, or otherwise, balance the equation. (9)

(b) (i) What is the colour of the light associated with the line emission spectrum of sodium? (4)

(ii) Explain how line emission spectra occur. (12)

(iii) What evidence do line emission spectra provide for the existence of energy levels in atoms? (6)

(iv) Why is it possible for line emission spectra to be used to distinguish between different elements? (3)

(c) State *Le Chatelier's principle*. (7)

When 30 g of ethanoic acid and 23 g of ethanol were placed in a conical flask and a few drops of concentrated sulfuric acid added, an equilibrium was set up with the formation of ethylethanoate and water.
The equilibrium is represented by the following equation.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

When the equilibrium mixture was analysed it was found to contain 10 g of ethanoic acid.

(i) Write the equilibrium constant expression, K_c, for this reaction. (6)

(ii) Calculate the value of the equilibrium constant, K_c. (12)

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

(a) (i) In what type of household product would you expect to find sodium hypochlorite? (4)

(ii) A solution of sodium hypochlorite, NaOCl, is labelled as having a concentration of 5% (w/v). Express the concentration of the sodium hypochlorite solution in grams per litre. (6)

100 cm^3 of this 5% (w/v) solution were reacted with excess chloride ion and acid according to the equation.

$$OCl^- + Cl^- + 2H^+ \rightarrow Cl_2 + H_2O$$

(iii) How many molecules of chlorine gas were liberated? (9)

(iv) What volume would this quantity of chlorine gas occupy at s.t.p.? (6)

(b) What are *alpha-particles* (α-particles)? (7)

Describe the experiment carried out by Rutherford and his co-workers that led to the discovery of the nucleus. Explain how Rutherford interpreted the results of this experiment to conclude that the atom has a nucleus. (18)

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

A

Distinguish between a batch and a continuous production process. (6)

Answer both of the following questions, (i) and (ii), in relation to <u>one</u> of the following processes:

ammonia manufacture **nitric acid manufacture** **magnesium oxide manufacture**

(i) In relation to your chosen chemical industry state <u>one</u> reason in favour of the Irish location of this industrial plant. (4)

(ii) Give a brief outline of the processes carried out in the manufacture of the main product, giving balanced chemical equations where relevant. (15)

or

B

Aluminium is extracted from bauxite.

(i) Where in Ireland is bauxite purified to produce alumina? (4)

(ii) Outline the steps involved in the extraction of alumina from bauxite, giving balanced chemical equations where relevant. (15)

(iii) Give <u>two</u> reasons why it is preferable to produce aluminium by recycling rather than by extracting it from its ore. (6)