IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

M03/420/H(3)

CHEMISTRY
HIGHER LEVEL
PAPER 3

Candidate number

Thursday 15 May 2003 (morning)

1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your candidate number in the box above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your candidate number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

Option B – Medicines and drugs

B1. (a) Many drugs are taken orally. State **three** other ways in which drugs may be taken by a patient. *[2]*

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(b) One common type of drug taken orally is the antacid. Antacids such as sodium hydrogencarbonate are taken to reduce stomach acidity.

(i) State the names of **two** metals, other than sodium, whose compounds are often used in antacids. *[1]*

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(ii) Give an equation for the neutralization of hydrochloric acid in the stomach by sodium hydrogencarbonate. *[1]*

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(iii) Explain how heartburn is caused. *[1]*

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(iv) Explain why dimethicone is added to some antacids. *[1]*

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B2. (a) (i) State what is meant by the term *analgesic*. Explain the difference in the mode of action of mild and strong analgesics. *[3]*

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(ii) State the general names of the **two** functional groups attached to the benzene ring in a molecule of aspirin. *[2]*

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(iii) The use of aspirin can have beneficial effects for the user, but can also produce some unwanted side effects. State **one** beneficial effect (other than its analgesic action) and **one** unwanted side effect. *[2]*

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(b) Morphine is a naturally occurring analgesic that can be converted into codeine.

(i) Calculate the difference in relative formula mass between morphine and codeine. *[1]*

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(ii) Explain what is meant by developing tolerance towards codeine and state why this is dangerous. *[2]*

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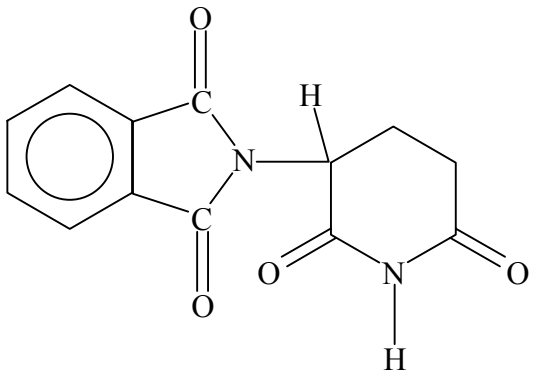
B3. Some drug molecules such as Thalidomide exist as stereoisomers. Thalidomide has the structure shown below.



(a) State the type of stereoisomerism shown by Thalidomide. Describe the feature responsible for this type of isomerism and identify it by means of a circle on the diagram. *[3]*

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(b) State **one** effect of **each** of these stereoisomers on pregnant women. *[2]*

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B4. Discuss **two** arguments for and **two** arguments against the legalization of cannabis. *[4]*

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Option C – Human biochemistry

C1. Polypeptides and proteins are formed by the condensation reactions of amino acids.

(a) Give the general structural formula of a 2-amino acid. *[1]*

(b) Give the structural formula of the dipeptide formed by the reaction of alanine and glycine. State the other substance formed during this reaction. *[2]*

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(c) State **two** functions of proteins in the body. *[2]*

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(This question continues on the following page)

(Question C1 continued)

(d) Electrophoresis can be used to identify the amino acids present in a given protein. The protein must first be hydrolyzed.

(i) State the reagent and conditions needed to hydrolyze the protein, and identify the bond that is broken during hydrolysis. *[4]*

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(ii) Explain how the amino acids could be identified using electrophoresis. *[4]*

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C2. Fats and oils can be described as esters of glycerol, $C_3H_8O_3$.

(a) (i) Draw the structure of glycerol. *[1]*

(ii) Glycerol can react with three molecules of stearic acid, $C_{17}H_{35}COOH$, to form a triglyceride. Deduce the number of carbon atoms in one molecule of this triglyceride. *[1]*

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(b) An oil sample containing 0.0100 mol of oil was found to react with 7.61 g of iodine, I_2. Determine the number of C═C double bonds present in each molecule of the oil. *[2]*

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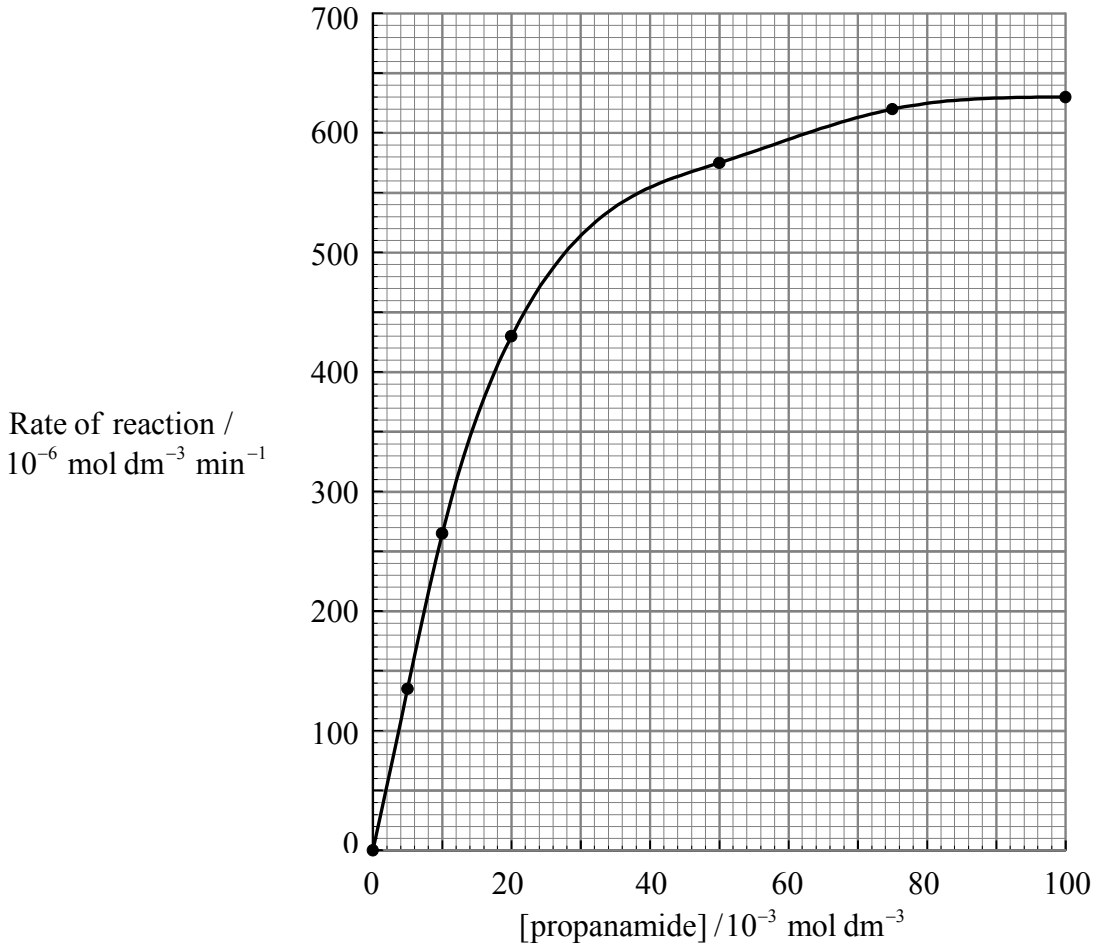
C3. Propanamide is hydrolysed to propanoic acid and ammonia by an enzyme. The rate of this reaction was measured at different concentrations of propanamide. The results are plotted on the following graph.



(a) Explain how an enzyme, E, can increase the rate of a reaction of a substrate, S, to form a product, P. *[2]*

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(This question continues on the following page)

(Question C3 continued)

(b) (i) Explain the shape of the curve on the previous page. *[4]*

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(ii) Determine the maximum rate, V_{max}, and the Michaelis constant, K_m, using the graph. *[2]*

V_{max} . . . . . K_m . . . . . .

Option D – Environmental chemistry

D1. The demand for drinking water continues to be a problem for the world. About 97 % of all the water on the planet is present in the seas and oceans and most of the rest is in ice caps or glaciers.

(a) One method used to provide drinking water from sea water is reverse osmosis, which uses a partially permeable (semipermeable) membrane.

(i) Outline what is meant by the terms *osmosis* and *partially permeable membrane.* *[2]*

Osmosis:

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Partially permeable membrane:

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(ii) Explain the technique of reverse osmosis used to produce drinking water from sea water. *[3]*

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(iii) Suggest **one** way in which a householder could reduce the amount of water used. *[1]*

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(This question continues on the following page)

(Question D1 continued)

(b) Water that allows marine life to flourish needs a high concentration of dissolved oxygen. Several factors can alter the oxygen concentration.

(i) State how an increase in temperature affects the oxygen concentration. *[1]*

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(ii) Eutrophication is a process that decreases the oxygen concentration of water. Explain how the accidental release of nitrates into a river can cause eutrophication. *[2]*

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D2. Waste water (sewage) from homes and industries varies greatly in its content, but it is desirable to treat it before it is returned to the environment, especially to reduce the Biological Oxygen Demand (BOD).

(a) State what is meant by the term *Biological Oxygen Demand*. *[2]*

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(b) Describe the main features of the activated sludge process used in secondary treatment, and state the main impurities removed during this treatment. *[5]*

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D3. The concentration of ozone in the upper atmosphere is maintained by the following reactions.

I. $O_2 \rightarrow 2O\bullet$ II. $O_2 + O\bullet \rightarrow O_3$ III. $O_3 \rightarrow O_2 + O\bullet$

The presence of chlorofluorocarbons (CFCs) in the upper atmosphere has led to a reduction in ozone concentration.

(a) State and explain, by reference to the bonding in O_2 and O_3, which of the reactions, I or III, needs more energy. *[4]*

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(b) Using CCl_2F_2 as an example, describe the reactions in which ozone depletion occurs in the upper atmosphere. Write an equation for each step in this process and explain the initial step by reference to the bonds in CCl_2F_2. *[5]*

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Option E – Chemical industries

E1. The oil industry converts most crude oil into fuels using several different processes, including fractional distillation, cracking and reforming.

(a) Describe and explain how crude oil is converted into several fractions in a fractionating column. *[4]*

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(b) All methods of cracking use high temperatures, but the other conditions vary, depending on the types of product required.

(i) State the name of a catalyst used in catalytic cracking. Write an equation for the cracking of the straight-chain molecule $C_{14}H_{30}$ into **two** products, assuming that only the central C–C bond breaks. *[2]*

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(ii) Hydrocracking is used to produce high-grade gasoline. Name the substance added to the feedstock and state **one** characteristic structural feature of the hydrocarbons produced. *[2]*

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(c) One type of reforming is called aromatization. Write an equation for this process, starting with hexane. State **one** use for the inorganic product formed. *[2]*

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E2. Several monomers are produced by the oil industry and used in polymer manufacture. Examples include propene and vinyl chloride.

(a) (i) Draw the structural formula of propene. *[1]*

(ii) Isotactic polypropene has a regular structure, while atactic polypropene does not. Draw the structure of isotactic polypropene, showing a chain of at least six carbon atoms. State and explain how its properties differ from those of atactic polypropene. *[3]*

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(b) Many plastic materials are disposed of by combustion. State **two** disadvantages of disposing of polyvinyl chloride in this way. *[2]*

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E3. (a) Chlorine is manufactured on a large scale from sodium chloride using a diaphragm cell. Describe how this is done. Identify the materials used and the products formed. Write half-equations for the processes occurring at each electrode. *[7]*

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(b) Explain why, on environmental grounds, this process is preferred to the mercury cell. *[2]*

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Option F – Fuels and energy

F1. Coal is the world's most abundant fossil fuel, although its combustion can cause problems of pollution. As well as carbon, coal may contain significant amounts of sulfur and non-combustible inorganic material.

(a) Describe the conditions under which coal was formed from plant remains. *[3]*

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(b) State **three** pollutants formed when coal is burned directly. *[2]*

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F2. Many portable electrical devices rely on various types of dry cell. The most common is the zinc-carbon cell, although alkaline cells are becoming more common.

(a) In the zinc-carbon cell, the space between the central carbon rod and the zinc outer casing is filled with a paste containing ammonium chloride and manganese(IV) oxide.

(i) One reaction occurring is $2NH_4^+ + 2e^- \rightarrow 2NH_3 + H_2$, for which $E^\ominus = +0.73$ V. Use the Data Booklet to identify the other main reaction occurring, and hence determine the $E^\ominus$ value for the cell. Write the overall cell reaction. *[2]*

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(ii) State the purpose of the manganese(IV) oxide. *[1]*

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(b) State **two** advantages of the alkaline cell over the zinc-carbon cell. *[2]*

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(c) A company manufactures a cell with a voltage of about 1.5 V. Suggest how the company could make each of the following.

(i) A cell with a voltage of about 1.5 V, but producing more power. *[1]*

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(ii) A battery with a voltage of about 6 V. *[1]*

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F3. Fuel cells have been described as the energy source of the future, because they are said to be non-polluting and can use renewable resources. One type uses hydrogen as the fuel and oxygen as the other substance consumed, with hot aqueous potassium hydroxide as the electrolyte. The overall equation for the process is $2H_2 + O_2 \rightarrow 2H_2O$, but the actual reactions taking place are different.

(a) Give the **two** half-equations for the reactions involving each reactant. *[2]*

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(b) Each kilojoule of chemical energy released in the oxidation of hydrogen in the fuel cell costs more than that released in the combustion of gasoline. Explain why fuel cells are considered to be more economical than gasoline engines. *[1]*

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F4. (a) Radioisotopes of the lighter elements can undergo decay by emitting a beta-particle or a positron. The type of decay can often be predicted from the neutron:proton ratio. For the radioisotope ^{28}Mg, calculate the neutron:proton ratio and write a nuclear equation to show the decay. Explain why ^{28}Mg undergoes this type of decay. *[4]*

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(b) Radioactive waste from nuclear power stations is often divided into high-level and low-level wastes. Describe the materials present in these wastes and the methods used for storage and disposal. *[6]*

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Option G – Modern analytical chemistry

G1. Organic compounds are often identified by using more than one analytical technique. Some of these techniques were used to identify the compounds in the following reactions.

$$\underset{\mathbf{A}}{C_3H_7Br} \rightarrow \underset{\mathbf{B}}{C_3H_8O} \rightarrow \underset{\mathbf{C}}{C_3H_6O}$$

(a) Using H_2O as an example, describe what happens, at a molecular level, during the absorption of infrared radiation. *[3]*

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(b) The infrared spectrum of **B** showed a broad absorption at 3350 cm^{-1}. The infrared spectrum of **C** did not show this absorption, but instead showed an absorption at 1720 cm^{-1}. Explain what these results indicate about the structures of **B** and **C**. *[2]*

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(c) The mass spectrum of **A** showed two lines of approximately equal height, one of which was at m/z = 122. State the m/z value of the other line and explain these observations. *[3]*

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(This question continues on the following page)

(Question G1 continued)

(d) The evidence in (b) and (c) indicates that each compound (**A**, **B** and **C**) could have two possible structures. Draw the two possible structures of **C**. *[2]*

(e) Fragmentation of **C** in a mass spectrometer produced lines with m/z values of 15 and 28, but none at values of 14 or 29. Identify **C** and explain how you used this information to do so. *[2]*

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(f) State the number of lines in the ^{1}H NMR spectrum of each of the structures in (d). *[2]*

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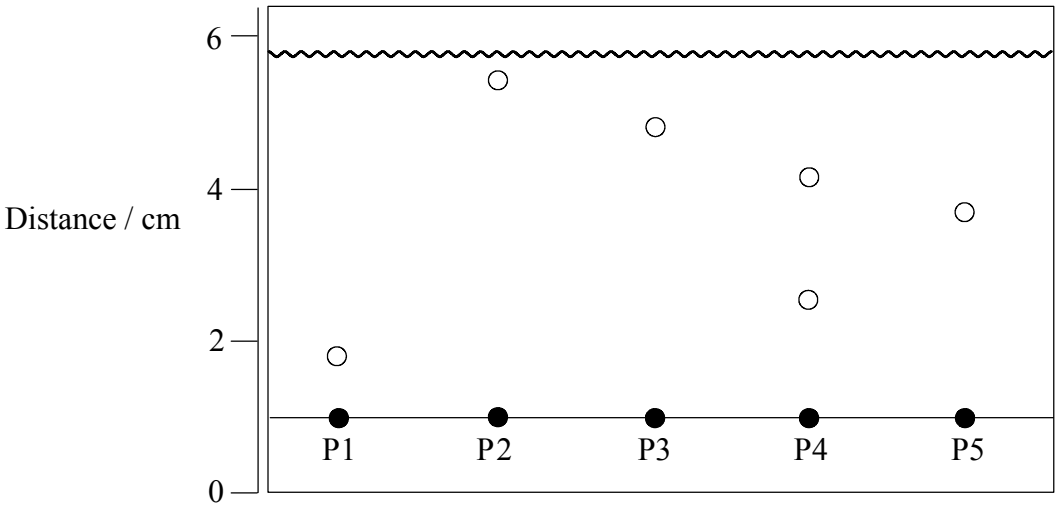
G2. A student used the technique of ascending paper chromatography in an experiment to investigate some permitted food dyes (labelled P1 - P5). The result is shown below.



(a) By reference to the diagram above, describe how the experiment would be carried out and explain the meaning of the terms *stationary phase, mobile phase, partition, solvent front* and R_f *value.* *[8]*

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(Question G2 continued)

(b) (i) Calculate the R_f value of P1. *[2]*

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(ii) State, giving a reason, whether P4 is a single substance or a mixture. *[1]*

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Option H – Further organic chemistry

H1. A student prepared a sample of compound **Y** from benzene as follows:

$$C_6H_6 \rightarrow \underset{\mathbf{X}}{C_6H_5CH_2CH_3} \rightarrow \underset{\mathbf{Y}}{C_6H_5CHClCH_3}$$

(a) (i) The first step was the conversion of benzene to compound **X**, using chloroethane as the reagent and aluminium chloride as a catalyst. Write the equation for the reaction and give equations for the mechanism. *[5]*

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(ii) Name the type of mechanism that occurs in the second step when **X** is converted to **Y**. *[1]*

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(This question continues on the following page)

(Question H1 continued)

(b) (i) Draw **two** structures for compound **Y**, showing the relationship between them. *[2]*

(ii) Explain the term *plane-polarized light* and describe how the optical isomers of **Y** could be distinguished using a polarimeter. *[4]*

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(iii) Explain why the sample of **Y** produced by the student did not show optical activity. *[2]*

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(c) Samples of compound **Y** and chlorobenzene are warmed separately with aqueous sodium hydroxide. State, with a reason, whether compound **Y** or chlorobenzene would react more slowly. *[2]*

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H2. The strength of an organic acid can be considered in terms of the breaking of the O–H bond in the molecule.

(a) State how the strength of an acid is related to the dissociation constant, K_a, of the acid, and to its pK_a value. *[2]*

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(b) By referring to their structures, explain the difference in the acid strengths of ethanol and phenol. *[2]*

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(c) Use the Data Booklet to find the pK_a values of the following acids. State how the presence of substituents in carboxylic acids affects their acid strengths. For each pair, explain the difference in acid strength by referring to the substituents.

- Ethanoic acid and propanoic acid
- Chloroethanoic acid and dichloroethanoic acid
- Chloroethanoic acid and fluoroethanoic acid

[5]

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