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Baccalauréat International
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CHEMISTRY
HIGHER LEVEL
PAPER 3

Candidate session number

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Monday 12 November 2012 (morning)

1 hour 15 minutes

Examination code

8	8	1	2	–	6	1	0	3

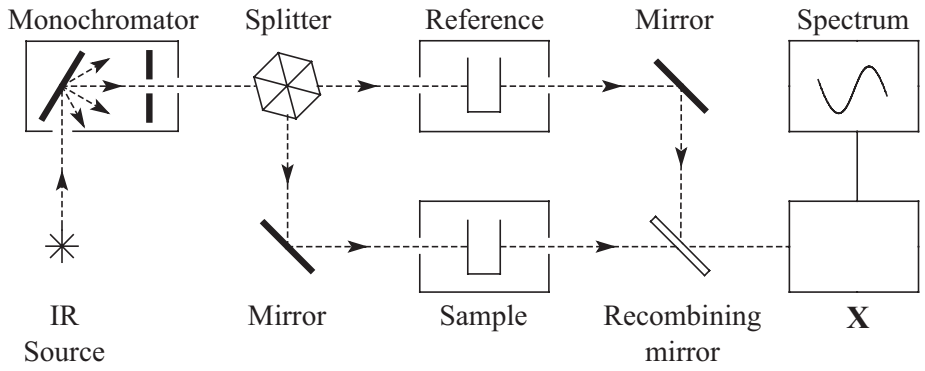
INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the ***Chemistry*** *Data Booklet* is required for this paper.
- The maximum mark for this examination paper is *[50 marks]*.

0140

Option A — Modern analytical chemistry

A1. The diagram below represents a simple double-beam infrared (IR) spectrometer.



(a) Describe briefly the function of the following components of the spectrometer. *[3]*

Monochromator:

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Splitter:

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Reference:

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(b) Identify the component of the spectrometer marked **X**. *[1]*

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A2. Chromatography is one of the most universal analytical techniques.

(a) State **one** qualitative and **one** quantitative use of chromatography. *[2]*

Qualitative:

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Quantitative:

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(b) Using column chromatography as an example, explain how components of a mixture interact with the stationary and mobile phases, and explain how the separation of the components is achieved. *[4]*

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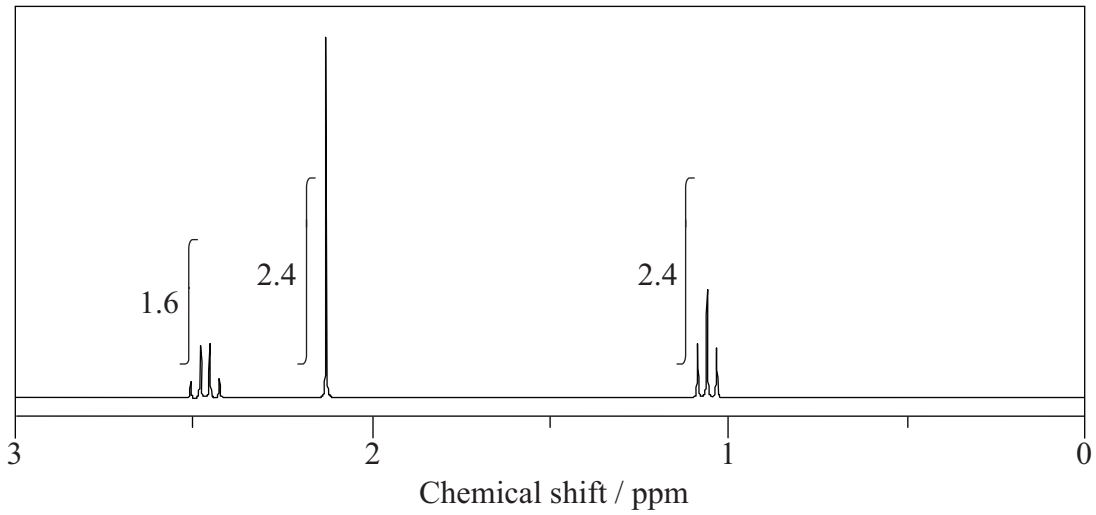
A3. The molecule of an unknown straight-chain compound consists of 4 carbon, 8 hydrogen, and 1 oxygen atoms. The ^{1}H NMR spectrum of the compound is given below (the numbers next to integration traces correspond to areas under each peak).



(a) Calculate the number of hydrogen atoms for peaks with chemical shifts of 2.15 and 2.4–2.5 ppm. An example for the peak at 1.0–1.1 ppm is given. *[2]*

Chemical shift / ppm	Number of hydrogen atoms
1.0–1.1	3
2.15	
2.4–2.5	

(b) Analyse the splitting pattern of each peak and determine the relative positions of hydrogen atoms in the molecule. One example is given. *[2]*

Chemical shift / ppm	Splitting pattern	Number of adjacent hydrogen atoms
1.0–1.1	triplet	2
2.15		
2.4–2.5		

(This question continues on the following page)

(Question A3 continued)

(c) Using the information from (a) and (b), deduce the structural formula of the organic compound. *[1]*

A4. Magnetic resonance imaging (MRI) is a medical application of NMR spectroscopy.

(a) State **one** advantage of MRI over X-ray medical imaging with reference to the electromagnetic spectrum. *[1]*

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(b) Outline how MRI is used to scan the human body. *[3]*

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A5. The concentration of transition metal complexes in water can be determined by visible and ultraviolet (UV-Vis) spectroscopy.

(a) Two octahedral chromium complexes are $[Cr(H_2O)_6]^{2+}$ and $[Cr(NH_3)_6]^{3+}$. Describe how the increase in oxidation state from Cr(II) to Cr(III) and the change in ligand from water to ammonia will affect the splitting of the d orbitals and the frequency of the light these complexes absorb. *[3]*

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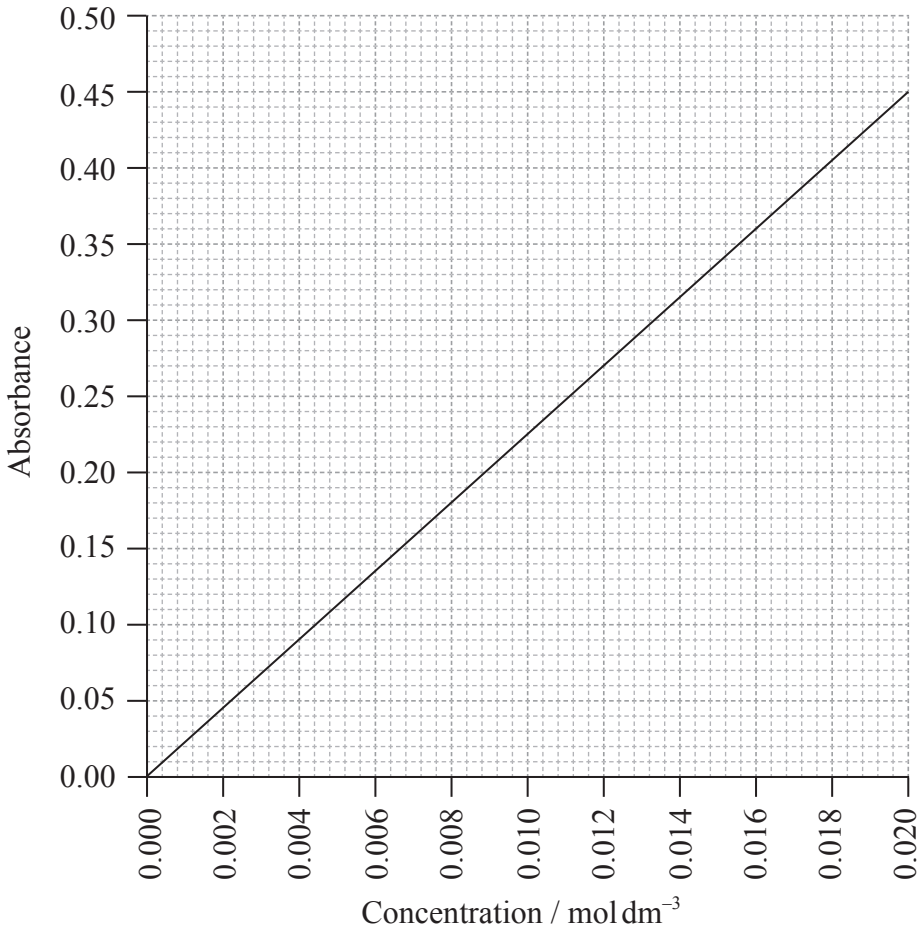
(Question A5 continued)

(b) A 5.00 cm^3 sample of aqueous solution containing a Cr(III) complex was diluted with water to a volume of 0.100 dm^3 and analysed by UV-Vis spectroscopy. The absorbance of the analysed solution was 0.320. Using the calibration curve below, determine the concentration of the Cr(III) complex in the **original** sample. *[2]*



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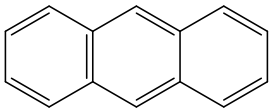
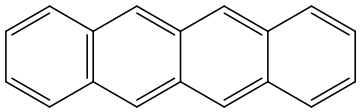
(Question A5 continued)

(c) One of the following organic compounds is colourless while the other is orange.



anthracene



tetracene

Predict, with reference to conjugation of double bonds, which compound (anthracene or tetracene) will absorb visible light and, therefore, be coloured. *[1]*

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Option B — Human biochemistry

B1. Carbohydrates are essential components of all living organisms.

(a) State what is meant by the term *dietary fibre*. *[1]*

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(b) Describe the importance of dietary fibre for a balanced diet and the prevention of various health conditions. *[3]*

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B2. There are several types of lipids in the human body. One of these types, triglycerides, might be made of fatty acids with different degrees of saturation.

(a) State **one** example of each of the following types of fatty acids (refer to Table 22 of the Data Booklet if necessary). *[3]*

Saturated:

. . . . . .

Mono-unsaturated:

. . . . . .

Poly-unsaturated:

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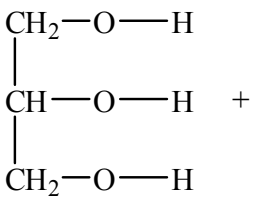
(b) Describe, by completing the equation below, the condensation of glycerol and the three fatty acids named in (a) to make a triglyceride. *[2]*



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(Question B2 continued)

(c) (i) State the names of **two** other types of lipids present in the human body. *[1]*

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(ii) Compare their composition with that of triglycerides. *[2]*

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B3. Proteins are products of polycondensation of 2-amino acids. In addition to their biochemical functions, proteins and individual 2-amino acids may act as acid–base buffers.

(a) At pH 7, a solution of alanine contains both the zwitterion and negatively charged (anionic) forms of alanine. Deduce the structural formula of each of these forms. Refer to Table 19 of the Data Booklet. *[2]*

Zwitterion:

Anionic:

(This question continues on the following page)

(Question B3 continued)

(b) State equations which show the buffer action of the solution from (a) when a small amount of strong acid is added and a small amount of strong base is added. *[2]*

Reaction with a strong acid:

Reaction with a strong base:

(c) Explain the differences between the primary and secondary structures of proteins and state the bond types responsible for maintaining these structures. *[2]*

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B4. State **two** differences in composition and **one** difference in structure between RNA and DNA. *[3]*

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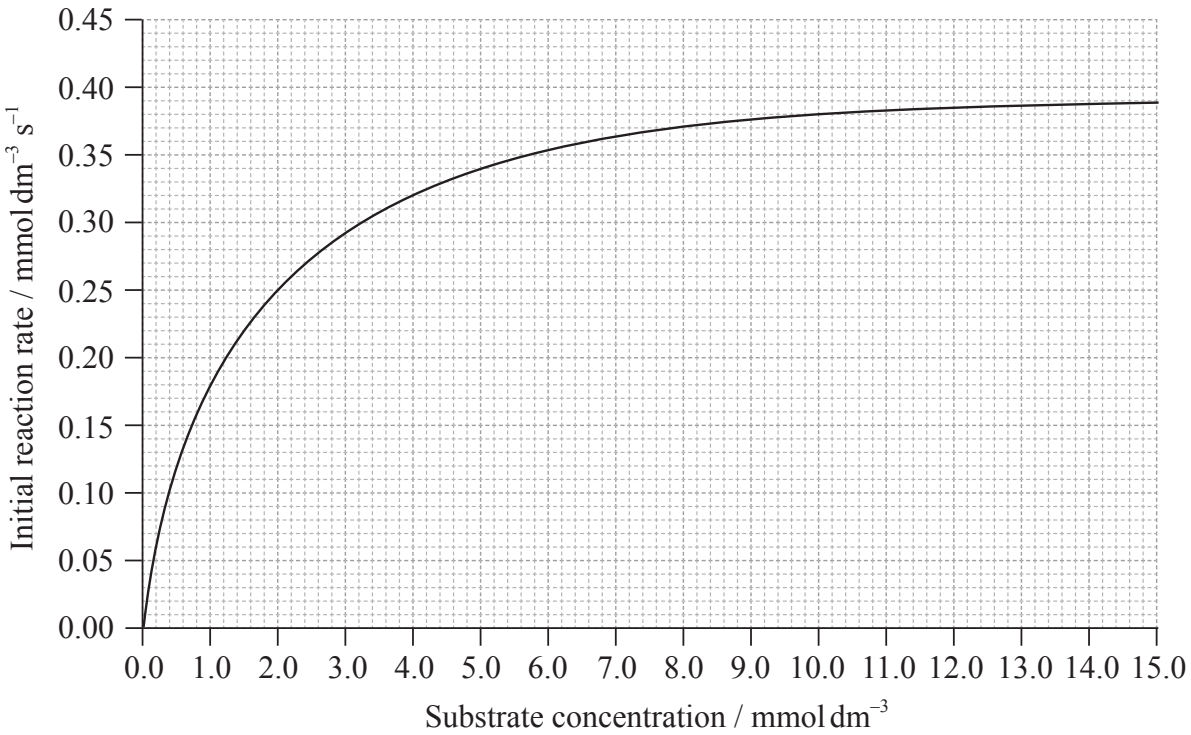
B5. The kinetics of simple enzymatic reactions can be described by the Michaelis–Menten equation that relates the initial reaction rate, V_0, to the concentration of the substrate, [S]. Determine V_{max} and K_m from the plot below, and explain the importance of these two constants. *[4]*



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Option C — Chemistry in industry and technology

C1. Worldwide a large quantity of iron is made every year. It is usually made in a continuous process in a blast furnace.

(a) State the purpose of **three** principal raw materials that are put into a blast furnace. *[3]*

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(b) State **two** balanced chemical equations which show the formation of liquid iron in a blast furnace. *[2]*

1. . . . . .
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2. . . . . .
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(c) Suggest **one** equation for a reaction occurring in a blast furnace which can be considered to be a neutralization reaction. *[1]*

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(This question continues on the following page)

(Question C1 continued)

(d) Describe **two** ways in which the brittleness of "pig iron" is reduced to produce steel which is more homogeneous, ductile and workable without it fracturing. *[2]*

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C2. In the oil industry surplus long-chain hydrocarbons are converted into shorter, more useful hydrocarbons by various kinds of cracking.

State whether each of the following are examples of homogeneous or heterogeneous catalysis. *[3]*

Steam cracking:

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Catalytic cracking:

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Hydrocracking:

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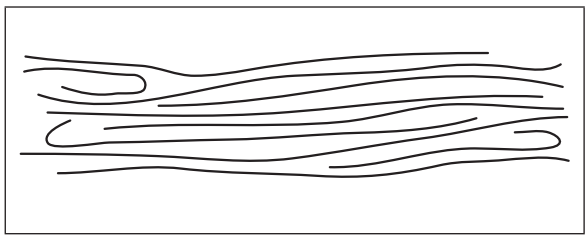
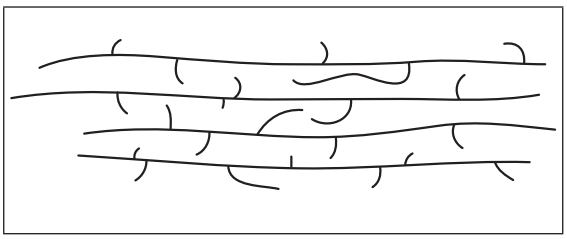
C3. The two diagrams below show the arrangement of molecules in two different types of polyethene, labelled **A** and **B**.



A



B

(a) Compare the strength of the intermolecular forces, density and flexibility of polymers **A** and **B**.

(i) Intermolecular forces: *[1]*

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(ii) Density: *[1]*

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(iii) Flexibility: *[1]*

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(This question continues on the following page)

(Question C3 continued)

(b) The polymer polyvinyl chloride (PVC), also known as poly(chloroethene), is hard and brittle when pure. Explain how the properties of this polymer can be modified to create a range of plastics which are more flexible and easily moulded. *[3]*

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C4. Kevlar is a polyamide polymer which is made in a very similar way to nylon, by reacting two monomer species together.

$$n\ H_2NC_6H_4NH_2 + n\ ClOCC_6H_4COCl \rightarrow H\text{–}[HNC_6H_4NHOCC_6H_4CO]_n\text{–}Cl + 2(n-1)\ HCl$$

(a) State the type of polymerization involved. *[1]*

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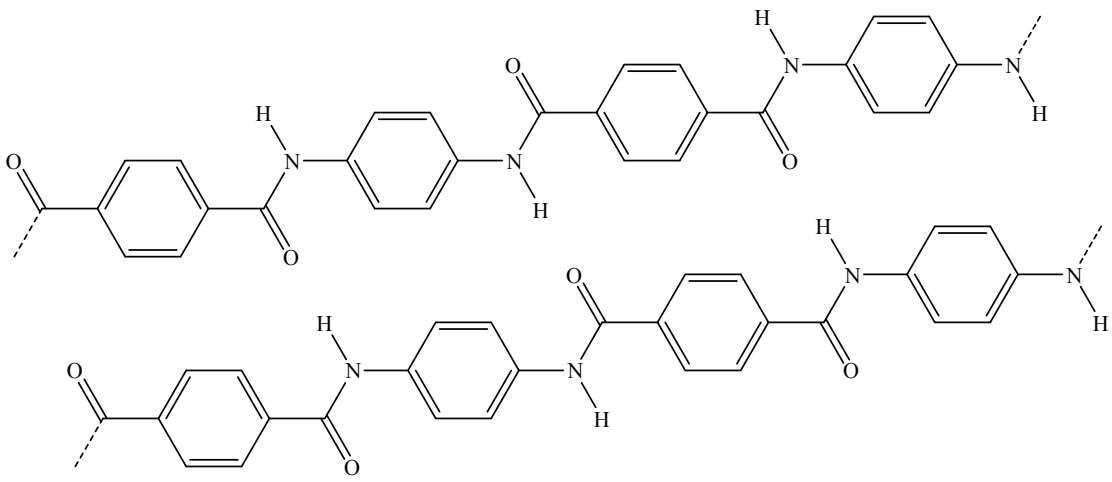
(b) The following diagram shows two adjacent molecules in a sample of solid Kevlar.



(i) Identify the strongest type of intermolecular force between the two molecules. *[1]*

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(ii) Annotate the diagram (above) by adding dotted lines to show the strongest intermolecular forces. *[1]*

(This question continues on the following page)

(Question C4 continued)

(c) Kevlar is five times as strong as steel, partly due to its strong intermolecular forces. State another feature of the molecules which gives Kevlar such great strength. *[1]*

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(d) Kevlar is very unreactive but dissolves in concentrated sulfuric acid.

(i) Suggest how the sulfuric acid is able to separate the Kevlar chains. *[2]*

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(ii) Evaluate the long-term environmental impact of Kevlar. *[2]*

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Option D — Medicines and drugs

D1. (a) Creating a new pharmaceutical product is a long and complex process. Outline the main stages of this process in the correct order. *[3]*

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(b) There are various ways to administer drugs to a patient. One of the common methods, parenteral, is also known as injection. State and describe **two** other methods of administering drugs. *[2]*

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(c) The efficiency of certain drugs is strongly dependent on the frequency and regularity of their administration. Explain the importance of patient compliance when the patient is treated with antibacterials. *[2]*

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D2. Physiological effects of drugs can be significantly reduced, enhanced or altered by other drugs or foods. The problem of drug interactions is particularly important for patients who consume excessive amounts of ethanol.

(a) State **one** possible adverse effect of consuming ethanol together with each of the following drugs. *[2]*

Aspirin:

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Diazepam (Valium®):

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(b) Detection of ethanol and accurate measurement of its levels in the human body is important for the effective treatment of patients and is required by law in certain cases (such as road accidents).

(i) With reference to the half-equations below, explain in terms of electron transfer, whether dichromate(VI) ions and ethanol are reduced or oxidized in the breathalyser. *[2]*

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$C_2H_5OH + H_2O - 4e^- \rightarrow CH_3COOH + 4H^+$$

Dichromate(VI) ions:

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Ethanol:

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(This question continues on the following page)

(Question D2 continued)

(ii) Explain how the concentration of ethanol is determined by the use of a fuel cell in the intoximeter. *[2]*

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D3. One approach to discovering new drugs involves evaluating a large collection of chemical compounds (compound library) synthesized individually by methods of traditional organic chemistry. Discuss **three** disadvantages of this approach. *[3]*

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D4. The efficiency of a drug depends on the polarity of its molecule. Explain how the polarity of a drug can be modified in order to increase its solubility in water and how it affects the distribution of the drug around the body. *[3]*

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D5. Tetrahydrocannabinol (THC) is the main psychoactive substance of cannabis. Describe the effects of THC and discuss the arguments for and against the legalization of cannabis.

(a) Effects: *[2]*

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(b) Arguments for legalization: *[2]*

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(c) Arguments against legalization: *[2]*

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Option E — Environmental chemistry

E1. Human activity leads to contamination of water with various pollutants. Before this water can be released to the environment or re-used, the pollutants have to be removed or their levels lowered.

(a) Heavy metals are released to the environment by mining. This is an example of a primary pollutant. State **two** other primary pollutants commonly found in waste water, and identify **one** source of each pollutant. *[2]*

Primary pollutant	Source
heavy metals	waste from mining

(b) Outline the processes involved in each of the following stages of water treatment **and** identify one type of substance removed in each case. *[3]*

Primary stage:

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Secondary stage:

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Tertiary stage:

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E2. The concentration of dissolved oxygen greatly affects the decomposition of organic material in water and the development of aquatic ecosystems.

(a) The following redox reactions represent bacterial decomposition of organic waste under different conditions. Identify the most likely environment (aerobic or anaerobic) for each reaction. *[2]*

Reaction	Environment
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$	
$CH_3COO^- + H_2O \rightarrow CH_4 + HCO_3^-$	
$2CH_2O + SO_4^{2-} \rightarrow 2CO_2 + H_2S + 2OH^-$	
$2CH_2O + O_2 + 2OH^- \rightarrow 2HCOO^- + 2H_2O$	

(b) Describe how eutrophication and thermal pollution decrease the concentration of dissolved oxygen in water. State **one** change in an aquatic ecosystem caused by these processes. *[3]*

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E3. Although more and more materials become available for recycling, some waste still needs to be disposed of. Two common methods of waste disposal are landfills and incineration. Compare the advantages and disadvantages of these methods. *[3]*

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E4. Ammonia is released to the atmosphere by micro-organisms and as a result of human activity. Explain how ammonia affects the process of acid deposition and acidity of the soil. Support your answer with equations of appropriate acid–base and redox reactions. *[4]*

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E5. Soil cation-exchange capacity (CEC) and pH affect the availability of macronutrients and micronutrients which are essential for plant growth.

(a) State what is meant by the term *soil cation-exchange capacity* and state **two** constituents of soil which are primarily responsible for its CEC. *[2]*

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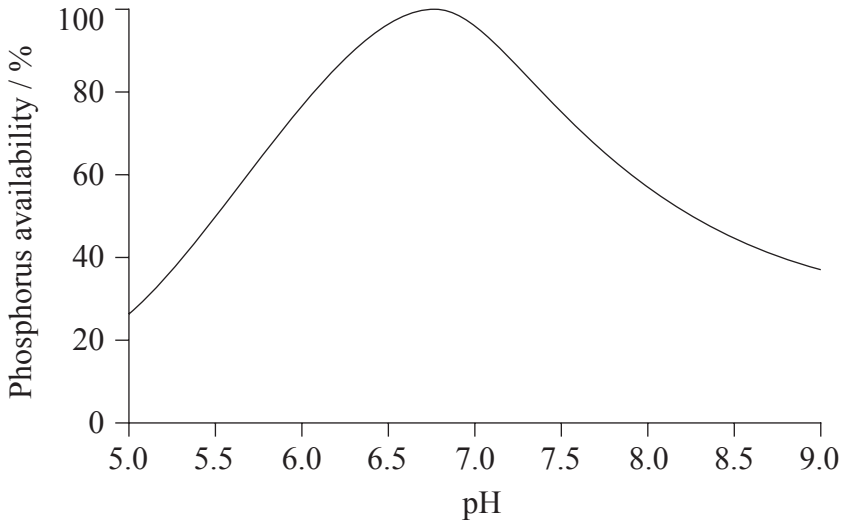
(b) The following graph represents the relative availability of phosphorus in soils with different pH values:



Discuss, using appropriate chemical equations, the effect of pH on the availability of iron and calcium, and how these nutrients affect the availability of phosphorus in acidic and alkaline soils. *[3]*

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E6. Extensive use of chlorofluorocarbons (CFCs) in the 20th century significantly decreased the concentration of stratospheric ozone. However, the greatest ozone depletion was observed in the Antarctic, far away from the industrialized countries where CFCs were released into the atmosphere. Outline the processes responsible for accelerated ozone depletion in polar regions. *[3]*

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Option F — Food chemistry

F1. Fats are complex molecules derived from fatty acids and glycerol. They are an important part of our diet and have many functions in the body including energy storage.

(a) Identify the main functional group present in

(i) all fats. *[1]*

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(ii) all fatty acids. *[1]*

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(b) Chocolate is a luxury food made from cocoa, sugars, unsaturated vegetable fats, milk whey and emulsifiers. Bars of chocolate sold in hot climates are made with a different blend of vegetable fats from bars sold in cold climates.

(i) Explain why fats with different physical properties are used for making chocolate sold in different climates. *[2]*

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(ii) Suggest how the structure of fat molecules used in a hot climate might differ from those used in a cold climate. *[2]*

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F2. Table 22 of the Data Booklet gives the structures of some fatty acids. Linolenic and linoleic acids are examples of essential fatty acids, known as omega-3 and omega-6 fatty acids.

(a) State the type of rancidity that fats containing essential fatty acids are most prone to, and identify the functional group in the fat molecules that is involved. *[2]*

Type of rancidity:

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. . . . . .

Functional group:

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(b) Identify **two** types of volatile compound that give rancid food its characteristic off odours and flavours. *[2]*

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(c) Describe **two** different ways, used in the food industry, to minimize the rate at which fats become rancid, and state **one** example of each. *[4]*

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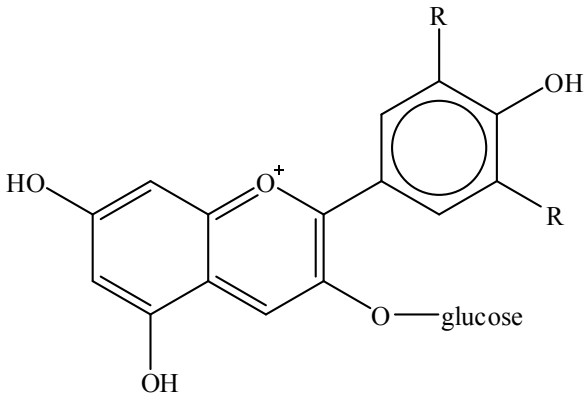
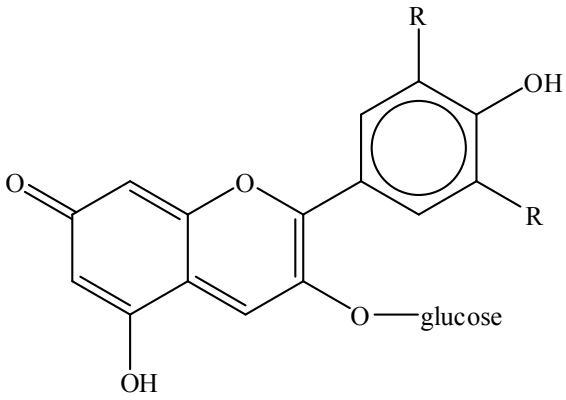
F3. Anthocyanins, the pigments which occur naturally in many flowers and fruits, are water soluble and often change colour as the temperature or pH changes. The diagrams show two structures of the same anthocyanin under different conditions.



A



B

(a) Explain why anthocyanins tend to be soluble in water. *[2]*

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(b) Using diagrams **A** and **B**, deduce whether structure **A** or structure **B** is more likely to exist in acid solution, and explain your answer. *[2]*

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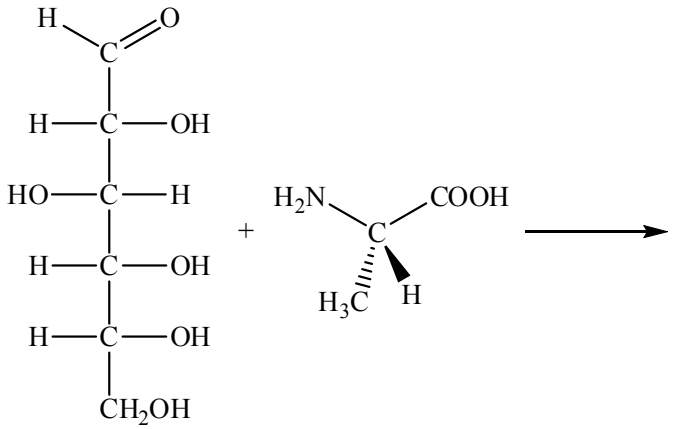
F4. The Maillard reaction is responsible for the non-enzymatic browning of food when it is cooked. The browning is caused by condensation reactions between the aldehyde groups of sugars and the amino groups of amino acids.

Deduce the products formed in the Maillard reaction, which takes place between the aldehyde group of glucose and the amine group of alanine during cooking. *[2]*



F5. (a) Explain how the "CORN" rule can be used to identify an enantiomer of alanine as either D- or L-alanine. *[3]*

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(b) Outline how optical isomerism can be used to test the authenticity of foods, such as the flavouring in a raspberry pie. *[2]*

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Option G — Further organic chemistry

G1. One of the challenges of synthetic organic chemistry is the preparation of substances with an increased number of carbon atoms. Hydrogen cyanide and organometallic reagents are commonly used for this purpose.

(a) State the equation for the reaction of hydrogen cyanide, HCN, with propanal, CH_3CH_2CHO. *[1]*

(b) State the reaction type in (a). *[1]*

. . . . . .

(c) State the general name for the product of the reaction in (a). *[1]*

. . . . . .

(This question continues on the following page)

(Question G1 continued)

(d) State the formula of the organic product of the reaction of propanal with ethylmagnesium bromide, CH_3CH_2MgBr. *[1]*

(e) Deduce a two-step reaction pathway for the conversion of 1-bromopropane, $CH_3CH_2CH_2Br$, into butanoic acid, $CH_3CH_2CH_2COOH$, using an organometallic reagent as the intermediate. State the appropriate equations and the reaction conditions for each step. *[3]*

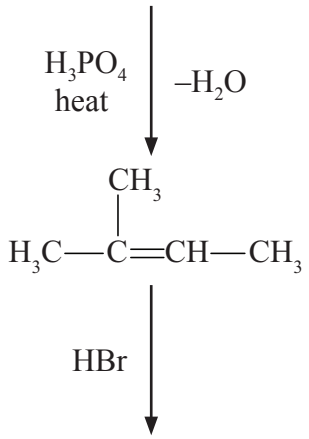
Step 1:

Step 2:

G2. Dehydration of alcohols leads to alkenes, which can be used as intermediates for further chemical transformations.

State the structural formula of the organic reactant and the structural formula of the final organic product needed to complete the following two-step reaction pathway. *[2]*

. . . . . .



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G3. Substituents attached to the benzene ring affect the direction of further substitution reactions.

(a) State an equation for the reaction of 2-bromopropane, $CH_3CHBrCH_3$, with methylbenzene, $C_6H_5CH_3$, and identify a suitable catalyst for the reaction. Your answer should include the structure of the organic product. *[2]*

(b) State the reaction type for the above reaction. *[1]*

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(c) State a reason why methylbenzene undergoes alkylation more readily than benzene. *[1]*

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G4. The acidity of phenols varies with the nature of substituents in their molecules. Table 15 of the Data Booklet provides some examples.

(a) State and explain how the presence of a nitro group attached to the benzene ring affects the acidity of phenols. *[3]*

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(b) State how the acidity of 3,5-dinitrophenol compares to that of phenol and 2,4,6-trinitrophenol. *[1]*

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(c) Suggest the pK_a value for 3,5-dinitrophenol. *[1]*

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G5. Acid anhydrides and acyl halides are widely used for the synthesis of esters and amides, including common drugs, such as aspirin and paracetamol.

(a) State the equation for the reaction of ethanoic anhydride, $(CH_3CO)_2O$, with phenylamine, $C_6H_5NH_2$. *[1]*

(b) State the reaction type in (a). *[1]*

. . . . . .

(c) State the equation for the reaction of ethanoyl chloride, CH_3COCl, with propan-2-ol, $(CH_3)_2CHOH$. *[1]*

(This question continues on the following page)

(Question G5 continued)

(d) Explain, using equations and curly arrows to represent the movement of electron pairs, the mechanism of the base hydrolysis of ethanoyl chloride. *[4]*