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CHEMISTRY
HIGHER LEVEL
PAPER 3

Friday 12 November 2010 (morning)

1 hour 15 minutes

Candidate session number

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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 in the spaces provided. You may continue your answers on answer sheets. Write your session 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.

0131

Option A — Modern analytical chemistry

A1. There is a wide range of analytical techniques available to chemists.

(a) State **two** reasons why the use of analytical chemistry techniques is important in society today. *[1]*

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(b) Identify which analytical technique is regularly used for

(i) testing for the presence of banned substances in the urine of athletes. *[1]*

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(ii) ^{14}C isotopic dating. *[1]*

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(iii) scanning of the human body to detect diseases such as cancer and multiple sclerosis. *[1]*

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A2. Infrared (IR) spectroscopy is widely used as a technique in analytical chemistry.

(a) Describe the operating principles of a double-beam infrared (IR) spectrometer. *[3]*

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(b) Explain what happens at a molecular level during the absorption of IR radiation by carbon dioxide, CO_2. *[3]*

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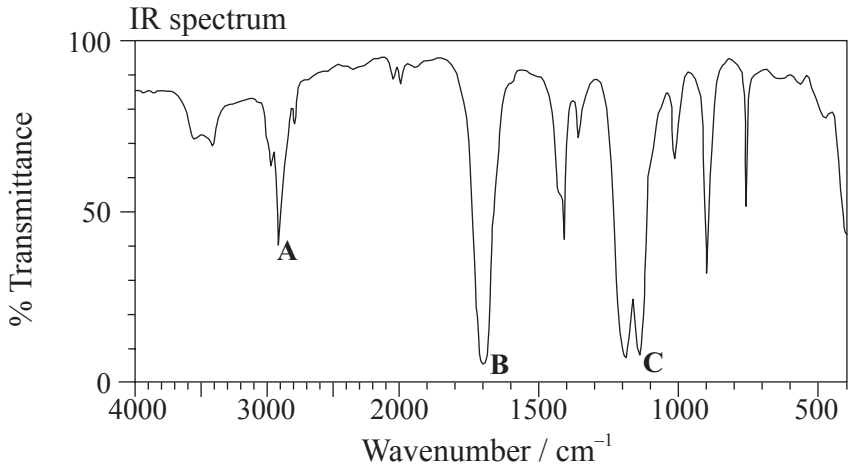
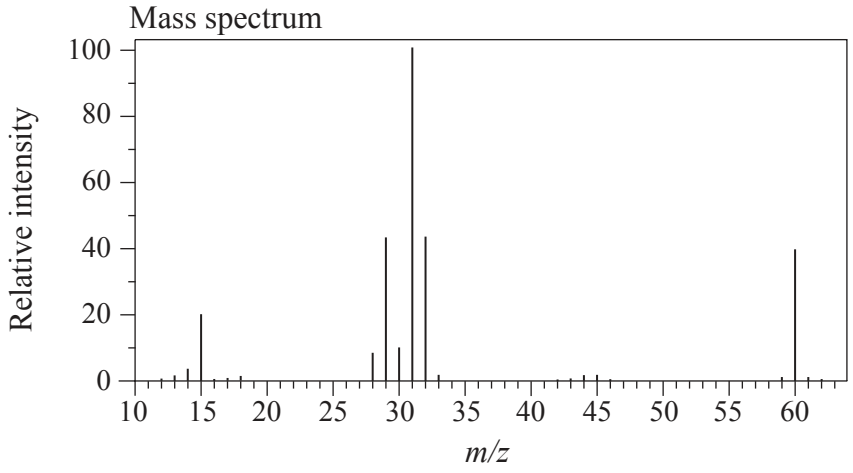
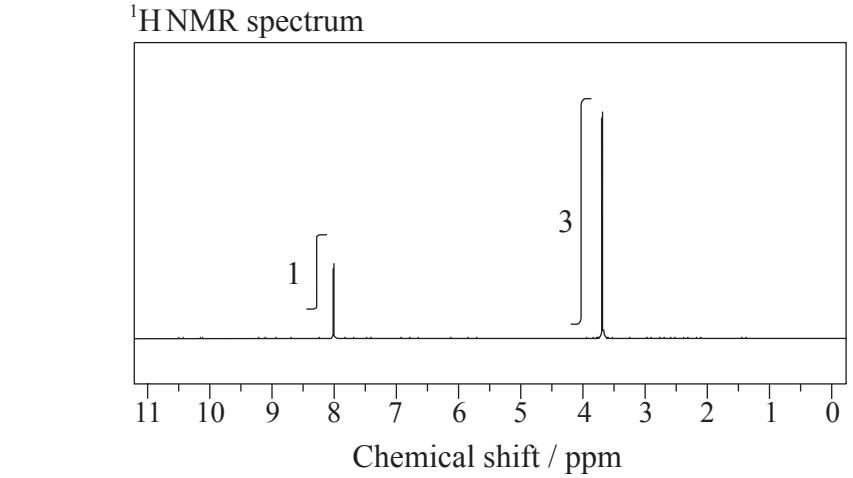
(This question continues on the following page)

(Question A2 continued)

(c) The IR spectrum, mass spectrum and ^{1}H NMR spectrum of an unknown compound, **Y**, of molecular formula $C_2H_4O_2$ are as follows.







[Source: SDBSWeb: http://riodb01.ibase.aist.go.jp/sdbs/ (National Institute of Advanced Industrial Science and Technology)]

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(Question A2 continued)

(i) Identify the bonds responsible for the peaks **A**, **B** and **C** in the IR spectrum of **Y**. *[2]*

A: . . . . . .

B: . . . . . .

C: . . . . . .

(ii) In the mass spectrum of **Y**, deduce which ions the *m/z* values at 31 and 29 correspond to. *[2]*

m/z = 31: . . . . . .

m/z = 29: . . . . . .

(iii) Identify the peaks at 3.76 and 8.07 ppm in the ^{1}H NMR spectrum. *[1]*

3.76 ppm: . . . . . .

8.07 ppm: . . . . . .

(iv) State what information can be obtained from the integration trace about the hydrogen atoms responsible for the peak at 3.76 ppm in the ^{1}H NMR spectrum. *[1]*

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(v) Deduce the structure of **Y**. *[1]*

(vi) Explain why tetramethylsilane (TMS) is suitable as a reference standard. *[2]*

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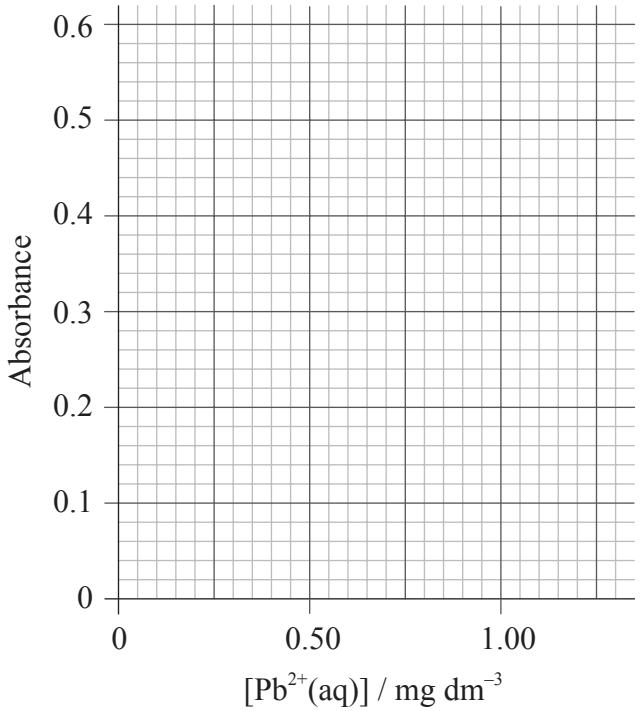
A3. According to recommendations from the *World Health Organization* (WHO), the maximum allowed concentration of lead(II) cations, $Pb^{2+}(aq)$, in drinking water is 0.001 mg dm^{-3}. The tap water taken from a building was analysed using atomic absorption (AA) spectroscopy to determine the concentration of $Pb^{2+}(aq)$. An AA spectrophotometer was calibrated and the following results were obtained.

$[Pb^{2+}(aq)]$ / mg dm^{-3}	**Absorbance**
0.25	0.110
0.50	0.220
0.75	0.340
1.00	0.450
1.25	0.560
Sample	0.170

(a) Draw the calibration curve and determine whether or not the water is within the WHO recommended maximum allowed concentration of lead(II) cations. *[3]*



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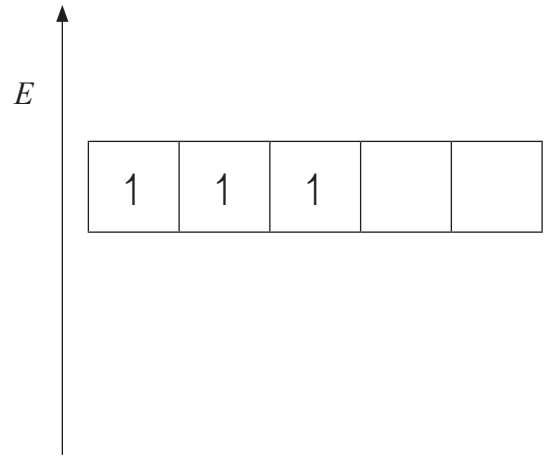
(Question A3 continued)

(b) Although both lead, Pb, and chromium, Cr, are metals, only chromium is classified as a transition metal and forms transition metal complexes, such as $[Cr(H_2O)_6]^{3+}$.

(i) The energy level diagram showing the electrons in the five 3d orbitals of a chromium atom is represented below. Draw the completed diagram showing the d orbitals in $[Cr(H_2O)_6]^{3+}$ after splitting. *[1]*



(ii) State and explain what happens to the splitting of the d orbitals if the ligand is changed from H_2O to NH_3. *[2]*

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Option B — Human biochemistry

B1. Foods such as rice, bread and potatoes are rich in carbohydrates. There are three main types of carbohydrate – monosaccharides, disaccharides and polysaccharides.

(a) Glucose, $C_6H_{12}O_6$, is a monosaccharide. When 0.85 g of glucose was completely combusted in a calorimeter, the temperature of 200.10 g of water increased from 20.20 °C to 27.55 °C. Calculate the energy value of glucose in J g^{-1}. *[3]*

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(b) (i) Draw the structural formula of α-glucose. *[1]*

(ii) Two α-glucose molecules condense to form the disaccharide maltose. Deduce the structure of maltose. *[1]*

B2. (a) Linoleic acid is an essential fatty acid whose formula is given in Table 22 of the Data Booklet. Determine the mass of iodine, I_2, which reacts with 100 g of linoleic acid. *[3]*

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(b) Fats, such as butter, are solid triglycerides. Explain why fats have a higher energy value than carbohydrates. *[1]*

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(c) The formula of stearic acid is also given in Table 22 of the Data Booklet. Explain why linoleic acid has a lower melting point compared to stearic acid. *[2]*

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B3. Steroidal-based hormones such as estradiol, progesterone and testosterone all contain a common structure.

(a) The structures of estradiol, progesterone and testosterone are given in Table 21 of the Data Booklet.

(i) State the names of **two** different functional groups present in progesterone but absent in estradiol. *[2]*

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(ii) Deduce the number of hydrogen atoms joined directly to the carbon atoms as part of the steroidal backbone in progesterone. *[1]*

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(b) The male steroidal hormones can be described as androgens. Testosterone is one such hormone. State **two** medical uses of testosterone as a steroid. *[2]*

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B4. Nucleic acids are natural polymers with exceptionally large relative molecular masses, made up of nucleotides. All cells in the human body, with the exception of red blood cells, contain deoxyribonucleic acid (DNA).

(a) James Watson, Francis Crick and Maurice Wilkins were awarded the 1962 Nobel Prize in Physiology or Medicine "for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material".

(i) Explain how the two helices are linked in the structure of DNA. *[2]*

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(ii) Describe the role of DNA in the storage of genetic information. The details of protein synthesis are not required. *[3]*

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(b) Outline the steps involved in DNA profiling and state **two** uses. *[4]*

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Option C — Chemistry in industry and technology

C1. "Oil should not be used as a source of energy because it has more important uses." Suggest **two** arguments that support the continued use of oil as an energy source, and **two** against. *[4]*

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C2. Thermal cracking, catalytic cracking and steam cracking are all used to convert alkane molecules into smaller molecules. Identify which **one** of the three types of cracking is used to crack a hexane molecule, C_6H_{14}, into propane and an alkene molecule, and state the equation involved. *[2]*

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C3. Exciting developments have taken place in recent years in the area of nanotechnology.

(a) Define the term *nanotechnology*, and state why it is of interest to chemists. *[2]*

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(b) Carbon nanotubes can be used to make *designer catalysts*. Describe the structure of carbon nanotubes. *[2]*

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(c) Suggest **two** concerns about the use of nanotechnology. *[2]*

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C4. (a) State the half-equations for the reactions taking place at the negative electrode (anode) and the positive electrode (cathode) in an alkaline hydrogen-oxygen fuel cell. *[2]*

Negative electrode (anode):

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Positive electrode (cathode):

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(b) A different type of cell has the half-equation below.

$$Li^+(polymer) + MnO_2(s) + e^- \rightarrow LiMnO_2(s)$$

Identify this type of cell. *[1]*

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C5. Consider the membrane chlor-alkali electrolysis cell, in which sodium chloride solution is electrolysed.

(a) For this process state the following.

(i) The material used for the membrane. *[1]*

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(ii) The material used for the positive electrode (anode). *[1]*

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(iii) The half-equation for the reaction that takes place at the positive electrode (anode). *[1]*

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(This question continues on the following page)

(Question C5 continued)

(b) Explain why the membrane cell is replacing both the mercury cell and the diaphragm cell. *[4]*

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(c) One of the products of the membrane cell is sodium hydroxide. State **three** of its important uses. *[3]*

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Option D — Medicines and drugs

D1. Dyspepsia, commonly known as indigestion, is due to excess acid in the stomach and can be treated using antacids.

(a) State the name of the acid found in the gastric juices of the stomach. *[1]*

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(b) Two examples of antacids are aluminium hydroxide and calcium carbonate. State the equations to show the action of each antacid. *[2]*

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(c) Antacid medicines often contain alginates and anti-foaming agents.

(i) Explain briefly how alginates prevent heartburn. *[2]*

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(ii) Explain why anti-foaming agents are added and state **one** example. *[2]*

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D2. (a) Two examples of mild analgesics are aspirin and paracetamol (acetaminophen). Paracetamol is often used as an alternative to aspirin. State **one** advantage and **one** disadvantage of the use of paracetamol. *[2]*

Advantage:

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Disadvantage:

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(b) Examples of strong analgesics are morphine, codeine and diamorphine (heroin). Their structures are shown in Table 20 of the Data Booklet.

(i) Identify **two** functional groups present in all three of these analgesics. *[2]*

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(ii) Identify **one** functional group present in morphine, but not in diamorphine. *[1]*

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(iii) State the name of the type of chemical reaction which is used to convert morphine into diamorphine. *[1]*

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D3. Three factors which can influence the mechanism of the action of a drug include geometrical isomerism, polarity and ring strain.

(a) For each of the following drugs, identify which **one** of these factors is involved. *[3]*

Increased potency of diamorphine compared to morphine:

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Penicillin:

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Cisplatin:

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(b) Explain the action of penicillin with reference to your answer in part (a). *[2]*

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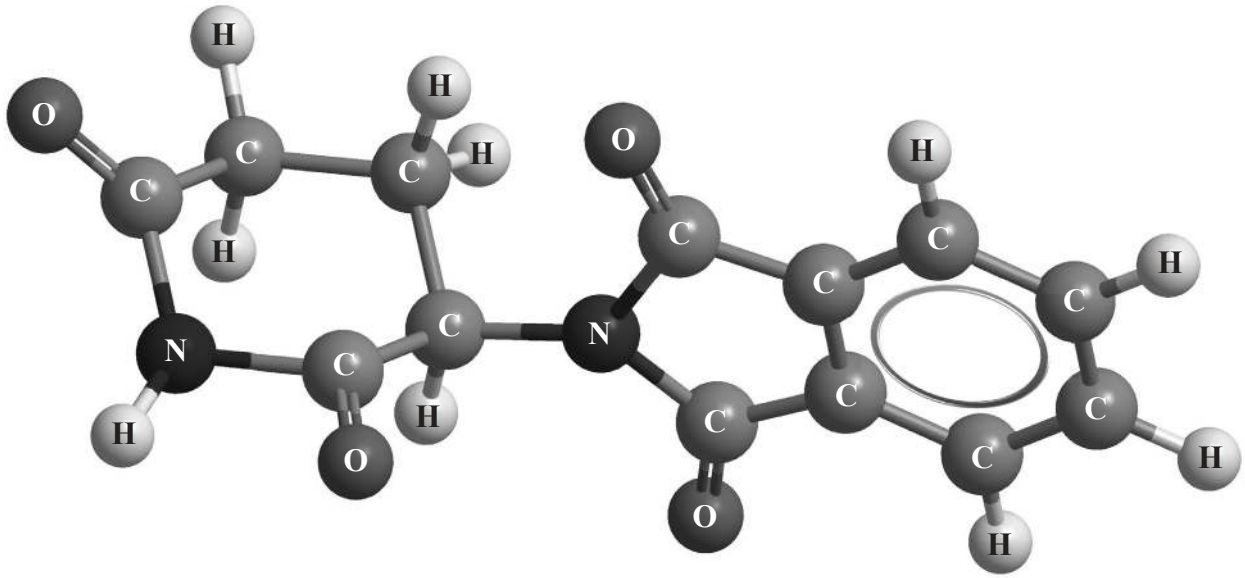
(Question D3 continued)

(c) Thalidomide has the following three-dimensional structure.



(i) Identify the chiral centre in the thalidomide structure (above) with an asterisk (*). *[1]*

(ii) Discuss the importance of chirality in the action of this drug by comparing the effects of each of the two enantiomeric forms. *[2]*

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D4. Two of the best known mind-altering drugs are lysergic acid diethylamide (LSD) and psilocybin. Using Table 20 of the Data Booklet, outline the essential structural similarities between the two drugs and describe the short-term effect of psilocybin. *[4]*

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Option E — Environmental chemistry

E1. Motor cars are convenient but produce pollution.

(a) List **three** pollutants, other than carbon dioxide, that are produced in the combustion engines of motor cars. *[3]*

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(b) Pollution can be decreased with the use of a catalytic converter. State an equation for **one** reaction that occurs in a catalytic converter. *[1]*

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(c) For the three pollutants that you listed in part (a), describe the polluting effect of each. An example has been given. *[3]*

Pollutant	Effect
Carbon dioxide	*Contributes to global warming*

E2. The quality of water can be affected by thermal pollution. State **one** major source of this pollution and discuss its effect on fish. *[3]*

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E3. One of the main causes of soil degradation is nutrient depletion.

(a) (i) State what you understand by the term *nutrient* when used in the context of soils. *[1]*

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(ii) Explain how agriculture removes soil nutrients and how they can be replaced. *[2]*

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(b) Discuss the effect on cation-exchange capacity (CEC) and on the availability of a nutrient such as magnesium as soil pH decreases from pH 7 to pH 3. *[3]*

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E4. (a) (i) Explain the dependence of the dissociation of diatomic oxygen, O_2, and ozone, O_3, on the wavelength of light. *[2]*

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(ii) State the equations for the formation and depletion of ozone in the stratosphere by natural processes. *[2]*

Formation of ozone:

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Depletion of ozone:

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(b) (i) State the equations for the depletion of ozone by the CFC, dichlorodifluoromethane, CCl_2F_2. *[3]*

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(ii) Use your answer to part (b) (i) to explain why CFCs are so effective at ozone depletion. *[2]*

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Option F — Food chemistry

F1. List **four** main factors that cause foods to spoil. *[2]*

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F2. (a) Distinguish between a *food dye* and a *food pigment*. *[2]*

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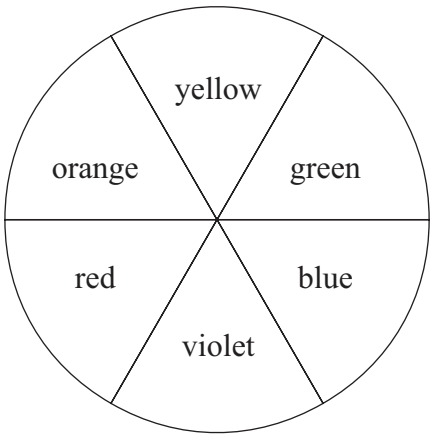
(b) The pigment in blueberries is an anthocyanin.



(i) With reference to the colour wheel above, explain how the pigment in blueberries causes them to be blue. *[2]*

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(This question continues on the following page)

(Question F2 continued)

(ii) List **two** other fruits that contain significant amounts of anthocyanin(s). *[2]*

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(iii) State the combination of pH and temperature that produces the strongest colour in anthocyanins. *[1]*

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(c) The structures of some anthocyanins are shown in Table 22 of the Data Booklet.

(i) Describe the structural feature of an anthocyanin molecule that causes it to be coloured. *[1]*

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(ii) With the aid of the anthocyanin structures in Table 22, discuss what is meant by the term *chromophore*, and how different anthocyanins may give different colours. *[2]*

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F3. Describe how emulsifiers assist the formation of emulsions and foams. *[2]*

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F4. The compound olestra has similar properties to saturated fats. It is used in margarine and related products, but it is not digested in the human gut. It is made from a disaccharide with up to eight fatty acid groups attached to it.

(a) (i) Explain what feature of the structure of glycerol (propane-1,2,3-triol) allows fatty acid molecules to become attached to it to make fats, and state the name of the reaction by which this occurs. *[2]*

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(ii) The structure of lactose, a typical disaccharide, is given in Table 21 of the Data Booklet. Suggest a reason why fatty acids can be attached to it. *[1]*

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(b) The fatty acids in olestra are smaller than those in cooking fats. Suggest a reason for this. *[1]*

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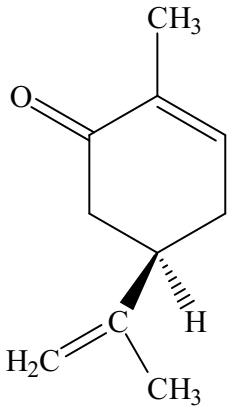
F5. The structure below shows –(*l*)-carvone.



–(*l*)-carvone has another optical isomer.

(a) State its name and, by means of a diagram, predict its structure. *[2]*

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(b) Describe the structural feature of the carvone molecule that allows it to exist as optical isomers. *[1]*

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(c) State the effect that the difference in the structures of the two optical isomers has on the flavour of the compounds. *[2]*

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(d) Explain what is meant by the –(*l*) notation, and how this is different to the (R) notation. *[2]*

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Option G — Further organic chemistry

G1. (a) Describe the structure of benzene, C_6H_6. *[3]*

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(b) State **two** pieces of evidence that support this description. *[2]*

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(c) The equation for the conversion of benzene into chlorobenzene in the presence of aluminium chloride is shown below.

$$C_6H_6 + Cl_2 \xrightarrow{AlCl_3} C_6H_5Cl + HCl$$

Explain the mechanism of this reaction, using curly arrows to represent the movement of electron pairs. *[4]*

(d) Identify the organic product in the following reaction. *[1]*

$$C_6H_6 + HNO_3 \xrightarrow{H_2SO_4}$$

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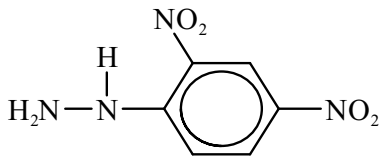
G2. Draw the structural formula of the **major** organic products, **A**–**D**, formed in the following reactions.

(a) $CH_3CH_2CH{=}CH_2 + HBr \rightarrow \mathbf{A}$ *[1]*

A:

(b) $CH_3CH_2COCH_3 +$  $\xrightarrow{H^+} \mathbf{B}$ *[1]*

B:

(c) $(CH_3)_2CO + HCN \rightarrow \mathbf{C}$ *[1]*

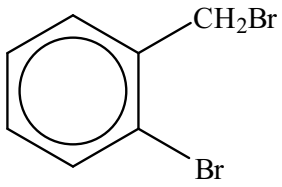
C:

(d) $CH_3CH_2CH_2MgBr + CH_3CH_2COCH_3 \xrightarrow{H_2O} \mathbf{D}$ *[1]*

D:

G3. (a) Deduce a two-step reaction pathway which can be used to convert propan-2-ol into 1,2-dibromopropane. Draw the structural formula of the organic product formed for each step and identify the reagents involved. *[4]*

(b) Deduce a two-step reaction pathway which can be used to convert methylbenzene into the molecule $BrCH_2(C_6H_4)Br$ shown below.



Draw the structural formula of the organic product formed for the first step, identify the reagents involved and state any specific reaction conditions or catalysts. *[3]*

G4. (a) State the formulas of the products **E** and **F** formed in the following reaction. *[2]*

$$CH_3COCl + 2CH_3CH_2NH_2 \rightarrow \mathbf{E} + \mathbf{F}$$

E: . . . . . .

F: . . . . . .

(b) Identify the nucleophile in the reaction in part (a). *[1]*

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(c) State the type of reaction occurring in part (a). *[1]*

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