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**CHEMISTRY**
**HIGHER LEVEL**
**PAPER 3**

Thursday 13 May 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.** State **two** reasons for the use of analytical techniques in today's society. *[2]*

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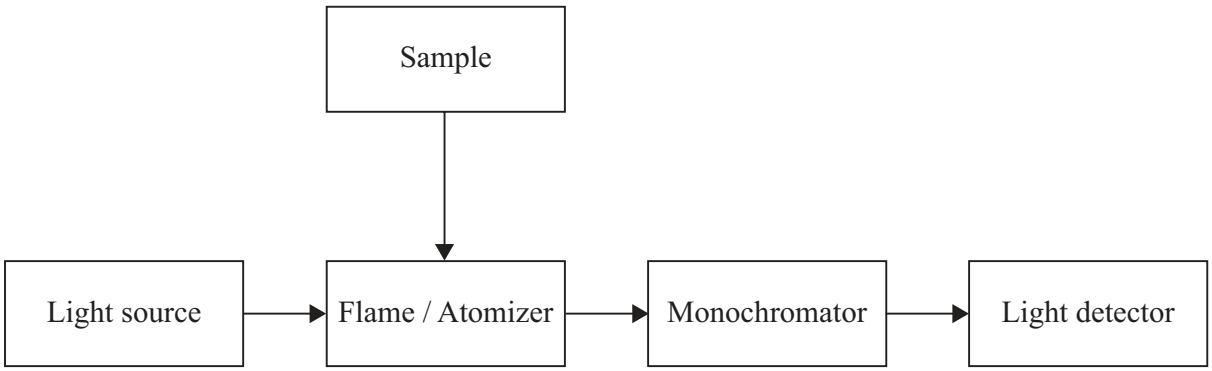
**A2.** A student analyses the amount of $Cu^{2+}$ in a water sample using atomic absorption spectroscopy. A simplified diagram of the atomic absorption spectrophotometer is shown below.




(a) State the essential characteristic of the lamp providing the light source. *[1]*

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(b) Describe what happens to the $Cu^{2+}$ (aq) ions when introduced into the atomizer. *[2]*

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*(This question continues on the following page)*

*(Question A2 continued)*

(c) Explain how the student can determine the concentration of $Cu^{2+}(aq)$ ions in the water sample using an atomic absorption spectrophotometer and a solution of 0.10 $mol\,dm^{-3}$ $CuSO_4$. *[4]*

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**A3.** (a) Explain why the nitrogen molecule, $N_2$, does not absorb infrared radiation. *[2]*

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(b) Describe **two** vibrations in the water molecule that absorb infrared radiation. *[2]*

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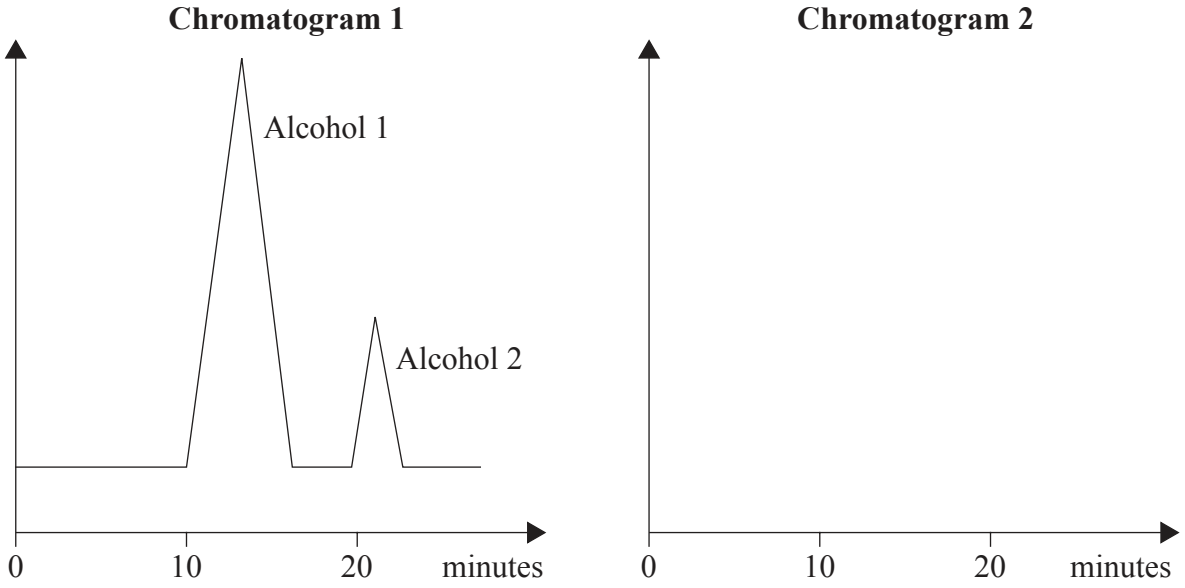
**A4.** (a) A mixture of two alcohols was analysed using high-performance liquid chromatography, HPLC, and produced chromatogram 1 below. In the space provided in chromatogram 2, sketch the chromatogram if the column of the chromatograph was less tightly packed and all other variables were kept constant. *[2]*




(b) Identify a possible mobile phase and stationary phase for HPLC and gas-liquid chromatography, GLC. *[4]*

| Chromatographic technique | Stationary phase | Mobile phase |
|---|---|---|
| HPLC | | |
| GLC | | |

(c) Deduce which technique, HPLC or GLC, can be used to analyse the urine sample of an athlete for the anabolic steroid, tetrahydrogestrinone, THG. *[1]*

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(d) Outline how the technique selected in part (c) would be carried out to confirm the presence of the steroid THG in the urine sample. *[2]*

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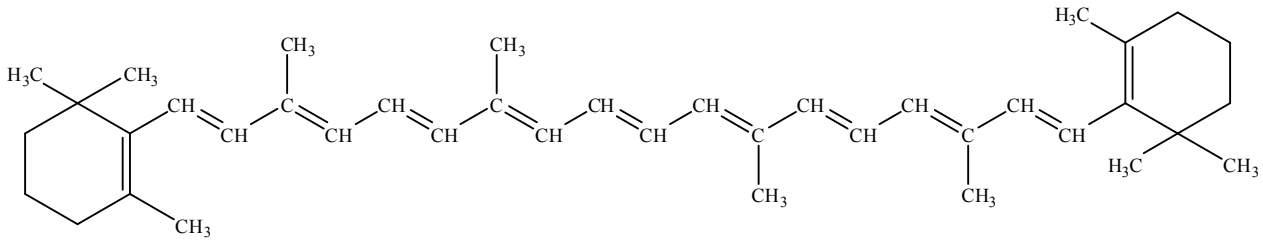
**A5.** β-carotene is involved in the formation of vitamin A. Its sources include carrots, broccoli and dark, leafy vegetables. Its structure is shown below.



Explain whether β-carotene absorbs ultraviolet or visible radiation. *[3]*

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**Option B — Human biochemistry**

**B1.** The energy value of food may be determined using a food calorimeter.

The combustion of 2.00 g of dried bread in a food calorimeter raised the temperature of 600 $cm^3$ water from 20.5 °C to 29.0 °C. Calculate the energy content of bread in kJ per 100 g. Specific heat capacity of water = 4.18 J $g^{-1}$ $K^{-1}$. *[4]*

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**B2.** Proteins are natural polymers.

(a) List **four** major functions of proteins in the human body. *[2]*

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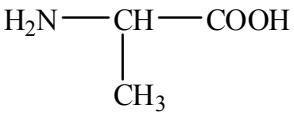
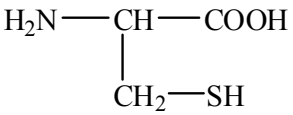
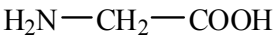
*(Question B2 continued)*

(b) Deduce the structures of **two** different tripeptides that can be formed when all three amino acids given below react together. *[2]*







(c) State the type of bonding that is responsible for the primary and secondary structures of proteins. *[2]*

Primary:

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Secondary:

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(d) Describe and explain the tertiary structure of proteins. Include in your answer all the bonds and interactions responsible for the tertiary structure. *[2]*

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**B3.** (a) State what is meant by the term *dietary fibre*. *[1]*

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(b) Describe the importance of a high fibre diet and list **two** health problems related to a low fibre diet. *[2]*

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**B4.** Calculate the number of carbon-carbon double bonds in linolenic acid, $C_{18}H_{30}O_2$, given that 7.7 g of iodine, $I_2$, react with 2.8 g of linolenic acid. *[2]*

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**B5.** Glucose can be used in the body either aerobically or during vigorous exercise, anaerobically. Compare the aerobic and anaerobic respiration of glucose in terms of the processes of oxidation/reduction and energy release. Write the overall equation for aerobic respiration. *[5]*

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**B6.** The nucleic acids, RNA and DNA, are polymers which are formed from nucleotides. Distinguish between the structures of RNA and DNA. *[3]*

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**Option C — Chemistry in industry and technology**

**C1.** Nanotechnology creates and uses structures that have novel properties because of their size.

(a) State the size range of structures which are involved in nanotechnology. *[1]*

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(b) Distinguish between physical and chemical techniques in manipulating atoms to form molecules. *[2]*

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(c) Discuss **two** implications of nanotechnology. *[2]*

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**C2.** Addition polymers are extensively used in society. The properties of addition polymers may be modified by the introduction of certain substances.

(a) For two different addition polymers, describe and explain **one** way in which the properties of addition polymers may be modified. *[4]*

Polymer one:

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Polymer two:

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(b) Discuss **two** advantages and **two** disadvantages of using poly(ethene). *[2]*

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**C3.** Detergents are one example of lyotropic liquid crystals.

(a) State **one** other example of a lyotropic liquid crystal and describe the difference between lyotropic and thermotropic liquid crystals. *[3]*

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(b) Name a thermotropic liquid crystal. *[1]*

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(c) Explain the liquid-crystal behaviour of the thermotropic liquid crystal named in part (b), on the molecular level. *[4]*

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**C4.** Chlorine, hydrogen and sodium hydroxide may all be produced by the electrolysis of concentrated sodium chloride solution using the membrane cell.

(a) Explain the purpose of the membrane in the membrane cell. *[1]*

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(b) State **two** major differences between the membrane cell and the diaphragm cell. *[2]*

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(c) Discuss why the membrane cell has replaced the mercury cell and the diaphragm cell in the production of chlorine, hydrogen and sodium hydroxide. *[3]*

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**Option D — Medicines and drugs**

**D1.** Drugs can be prescribed for treating various diseases and assisting in healing the human body, however, any drug presents potential risks. The properties of three drugs are summarized below.

| Drug | Physiological effect | Side-effects | Therapeutic window |
|---|---|---|---|
| **A** | high | severe | medium |
| **B** | moderate | moderate | narrow |
| **C** | low | minimal | wide |

Suggest which drug (**A**, **B** or **C**) could be

(a) considered safe enough to be taken by patients without supervision. *[1]*

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(b) administered **only** by qualified staff. *[1]*

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(c) used **only** in a medical emergency. *[1]*

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**D2.** Antiviral drugs are used for the treatment of HIV and other viral infections.

Describe **two** ways in which antiviral drugs work. *[2]*

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**D3.** Mild analgesics such as aspirin, and strong analgesics such as opiates, differ not only in their potency but also in the ways they act on the central nervous system.

(a) Describe how mild and strong analgesics provide pain relief. *[2]*

Mild analgesics:

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Strong analgesics:

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(b) Discuss **two** advantages and **two** disadvantages of using morphine and other opiates for pain relief. *[4]*

Advantages:

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Disadvantages:

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(c) Explain why heroin is a more potent drug than morphine. *[2]*

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**D4.** Fluoxetine hydrochloride (Prozac®) is a common depressant. Depressants have many therapeutic uses.

(a) State **three** other common depressants. *[3]*

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(b) Describe **one** effect, other than relieving depression, of moderate doses of depressants on patients. *[1]*

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**D5.** Compound libraries are widely used in the pharmaceutical industry for the development of new drugs. Such libraries can be quickly created by combinatorial and parallel syntheses.

(a) Explain how combinatorial and parallel chemistry can be used to build compound libraries. *[4]*

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(b) Outline the role of computers in drug design. *[2]*

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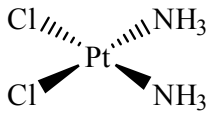
**D6.** Planar complexes of the formula $[Pt(NH_3)_2Cl_2]$ can exist as two isomers. One of these isomers, *cisplatin*, is a common anti-cancer drug with the following structural formula.




Draw a structural formula for the second isomer and state the type of isomerism represented by these two complexes. *[2]*

Type of isomerism: . . . . . .

**Option E — Environmental chemistry**

**E1.** The greenhouse effect maintains the Earth's average temperature at a habitable level. The components of the Earth's atmosphere responsible for this effect are called greenhouse gases.

(a) Major greenhouse gases are water vapour and carbon dioxide. State **two** other greenhouse gases. *[2]*

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(b) Describe how greenhouse gases cause the greenhouse effect. *[3]*

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(c) Discuss **three** possible implications of global warming on world food production. *[3]*

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**E2.** Disposal of radioactive waste is a major ecological concern.

(a) State **one** source of low-level radioactive waste and **one** source of high-level radioactive waste. *[2]*

Low-level waste:

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High-level waste:

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(b) Consider the following types of radioactive waste.

| Type | Waste | Isotopes | Half-life | Emissions |
|---|---|---|---|---|
| **A** | syringes and other disposable materials used in radiotherapy | $^{90}Y$ | 64 hours | $\beta^-$ |
| **B** | diluted aqueous solution of cobalt-60 complexes | $^{60}Co$ | 5.3 years | $\beta^-$, $\gamma$ |
| **C** | partially processed solid materials from a nuclear reactor | U, Pu, Am and other actinides | $10^3$–$10^9$ years | $\alpha$, $\gamma$ |

Identify which method can be used for the disposal of radioactive wastes **A**, **B** and **C**.

(i) Vitrification followed by long-term underground storage: *[1]*

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(ii) Storage in a non-shielded container for two months followed by the disposal as normal (non-radioactive) waste: *[1]*

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(iii) Ion-exchange and adsorption on iron(II) hydroxide, storage in a shielded container for 50 years, then mixing with concrete and shallow land burial: *[1]*

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**E3.** Chlorofluorocarbons (CFCs) and other ozone-depleting agents reduce the concentration of ozone in the Earth's stratosphere and increase the exposure of humans and other living organisms to dangerous UV radiation.

(a) State **two** alternatives to CFCs. *[1]*

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(b) State **two** disadvantages of using alternatives to CFCs. *[2]*

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(c) Describe, using equations, a two-step mechanism of ozone decomposition catalysed by nitrogen monoxide. *[2]*

Step 1:

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Step 2:

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(d) Explain why UV radiation with $\lambda = 300 - 330\,\text{nm}$ contributes to photochemical decomposition of ozone but not to the formation of ozone from oxygen. *[3]*

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**E4.** (a) Describe the atmospheric and geographical conditions that favour the formation of photochemical smog. *[3]*

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(b) Peroxyacylnitrates (PANs) are common secondary pollutants in photochemical smog. Write a chemical equation for the formation of a PAN. *[1]*

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**Option F — Food chemistry**

**F1.** The preservation of food is important around the world.

(a) Explain the meaning of the term *shelf life*. *[2]*

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(b) Discuss **two** factors that can affect the shelf life of food. *[4]*

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**F2.** (a) Describe the differences in the structure between the saturated fatty acid $C_{16}H_{32}O_2$ and the unsaturated fatty acid $C_{16}H_{26}O_2$. *[3]*

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(b) Describe how $C_{16}H_{26}O_2$ can be converted to $C_{16}H_{32}O_2$. *[3]*

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(c) Fatty acids are components of fats and oils. Describe **one** advantage of the products formed by hydrogenating fats and oils. *[1]*

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**F3.** (a) Define the term *antioxidant* and state its use. *[2]*

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(b) Discuss **one** disadvantage of using natural and synthetic antioxidants. *[2]*

Natural antioxidants:

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Synthetic antioxidants:

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(c) Two types of antioxidants are reducing agents and chelating agents. Explain how their actions are different. Name **one** naturally occurring source for each type of antioxidant. *[4]*

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**F4.** The structures of some anthocyanins and carotenoids are given in Table 22 of the Data Booklet. Deduce and explain whether anthocyanins and carotenoids are water-soluble or fat-soluble. *[4]*

Anthocyanins:

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Carotenoids:

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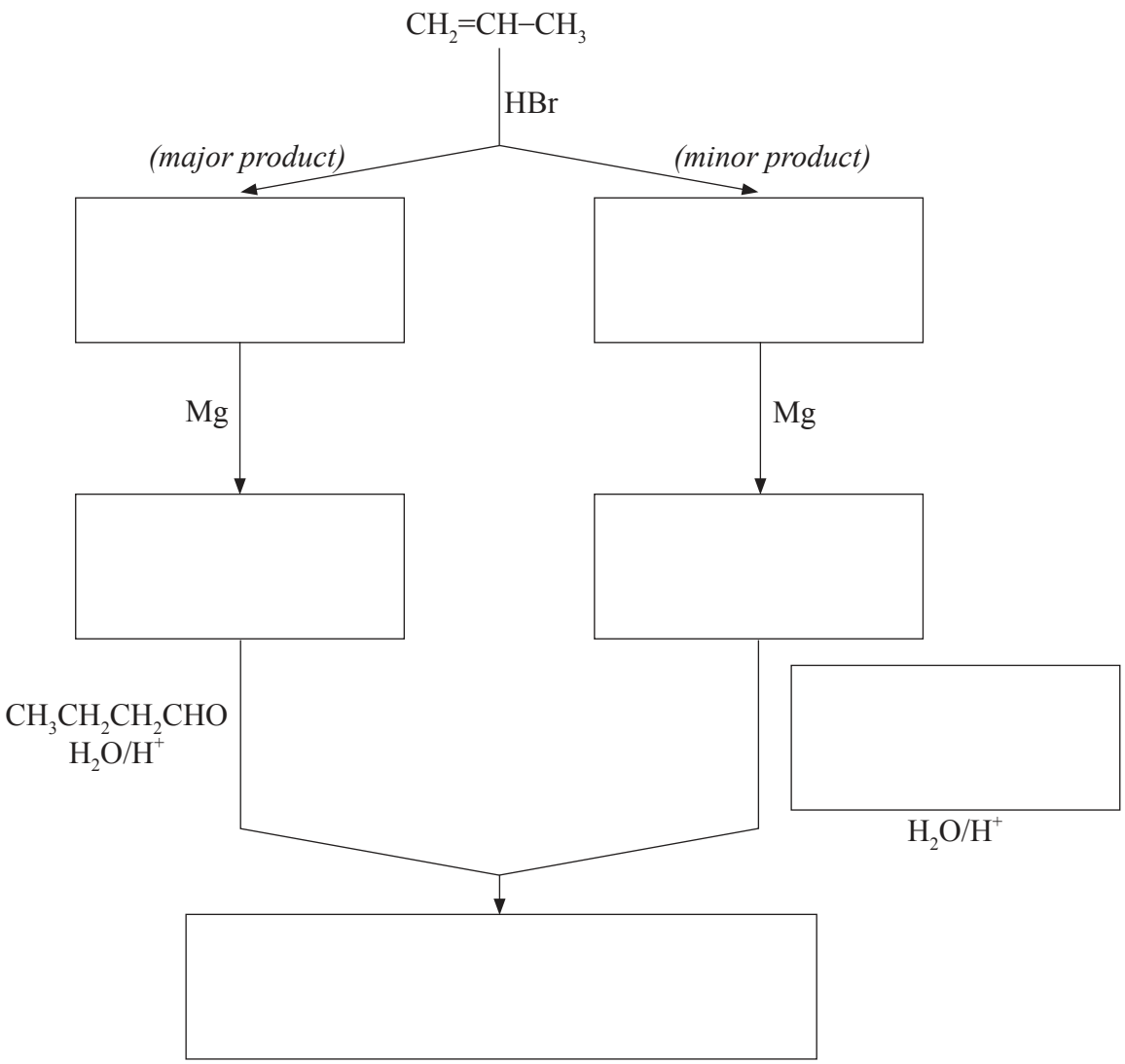
**Option G — Further organic chemistry**

**G1.** Addition of hydrogen halides to unsymmetrical alkenes produces a mixture of halogenoalkanes. The latter can be converted into Grignard reagents by reaction with magnesium metal and then used for the preparation of various organic molecules with an increased number of carbon atoms.

(a) State in the boxes below, the formulas of the organic substances needed to complete the following reaction pathways. *[4]*




*(This question continues on the following page)*

*(Question G1 continued)*

(b) Describe, using equations and curly arrows to represent the movement of electron pairs, the mechanism of the reaction between propene and hydrogen bromide. Compare the relative stabilities of the two intermediate carbocations which lead to the formation of the major and minor products. *[4]*

**G2.** The acidity of carboxylic acids depends on the carbon chain length and the nature of substituents in their molecules. Table 15 of the Data Booklet provides some examples.

(a) State and explain how the presence of halogen atoms in the hydrocarbon chain affects the acidity of carboxylic acids. *[3]*

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(b) State how the acidity of 3-chloropropanoic acid compares to that of propanoic acid and chloroethanoic acid. *[1]*

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(c) Suggest the p$K_a$ value for 3-chloropropanoic acid. *[1]*

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**G3.** Alkylation of benzene is a common industrial process that allows substituents to be introduced into the aromatic ring.

(a) State an equation to show the reaction of benzene with chloromethane in the presence of a Lewis acid. *[1]*

(b) Describe, using equations and curly arrows to represent the movement of electron pairs, the mechanism of the above reaction. *[4]*

**G4.** When benzene undergoes alkylation, more than one substituent can be introduced into the aromatic ring. In contrast, acylation of methylbenzene usually gives a single organic product.

(a) State an equation, using structural formulas, to show the reaction of methylbenzene with ethanoyl chloride in the presence of a Lewis acid. *[2]*

(b) Give **two** reasons why other organic products do not form in this reaction. *[2]*

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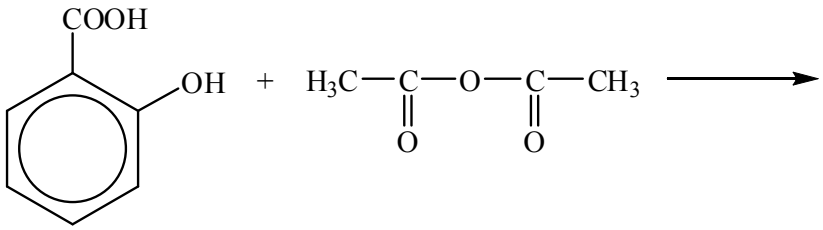
**G5.** State the structural formulas of the **two** organic products formed in the reaction below and state the reaction type. *[3]*




Reaction type: . . . . . .