Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 3

Friday 15 May 2015 (morning)

Candidate session number

1 hour

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 **[40 marks]**.

Option	Questions
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2215 – 6118

33 pages

Option A — Modern analytical chemistry

1. Chemists have developed a wide variety of spectroscopic and chromatographic techniques.

(a) For each of the following analytical investigations, identify the technique that would be the most appropriate. [5]

	Investigation	Technique
A	Determining the sodium ion concentration in bottled water	. . . . .
B	Determining whether an organic molecule contains a C=O bond	. . . . .
C	Determining the molecular mass of an organic molecule	. . . . .
D	Determining whether an ink comprises just one compound or a mixture of compounds	. . . . .
E	Determining the number of different hydrogen atom environments in a molecule	. . . . .

(b) Three of the techniques you have answered above involve measuring the absorption of electromagnetic radiation.
List the letter associated with each of these three in order of increasing **frequency** of the radiation. [1]

Lowest frequency ⟶ Highest frequency

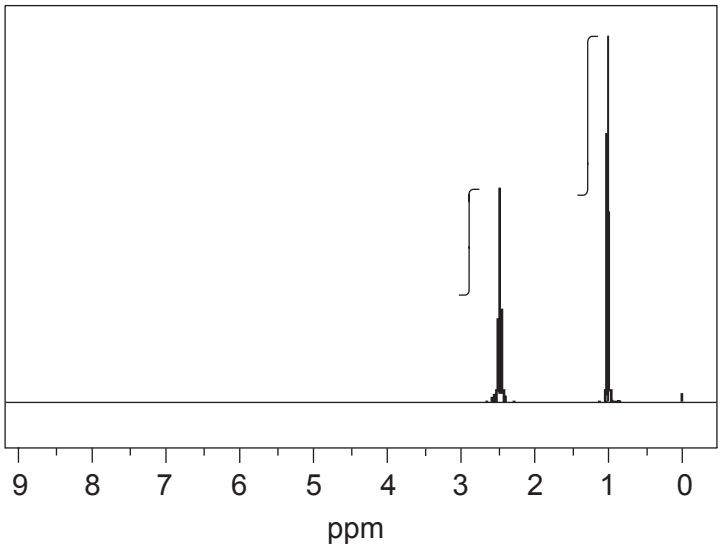
. . . . . .

(Option A continues on the following page)

(Option A continued)

2. NMR spectroscopy is one of the most powerful analytical tools for determining molecular structure.

The ^{1}H NMR spectrum, including the integration trace, of a ketone with relative molecular mass 86 is shown below.



[Source: SDBS web: www.sdbs.riodb.aist.go.jp (National Institute of Advanced Industrial Science and Technology, 2014)]

Deduce the structural formula of the compound, justifying your choice. [3]

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(Option A continues on the following page)

(Option A continued)

3. Consider the compound chloroethene, CH_2=CHCl.

(a) Deduce **two** features you would expect to observe in its mass spectrum. [2]

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(b) Predict **two** features you would expect to observe in its infrared (IR) spectrum. [2]

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(c) Explain what occurs at a molecular level when a bond absorbs IR radiation. [2]

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(Option A continues on the following page)

(Option A continued)

4. The image shown below is an MRI scan of a knee.

[Source: www.ganfyd.org]

(a) (i) State which type of atoms are detected by an MRI scan. [1]

. . . . . .

(ii) Suggest why some regions of the image are a darker colour than others. [1]

. . . . . .
. . . . . .

(Option A continues on the following page)

(Option A, question 4 continued)

(b) (i) State the type of radiation used and the other condition required to generate the scan. [2]

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. . . . . .
. . . . . .

(ii) Outline why MRI is less harmful to the patient than X-ray based techniques. [1]

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End of Option A

Option B — Human biochemistry

5. Proteins are made of long chains of amino acids.

(a) (i) Explain how individual amino acids can be obtained from proteins for chromatographic separation. [2]

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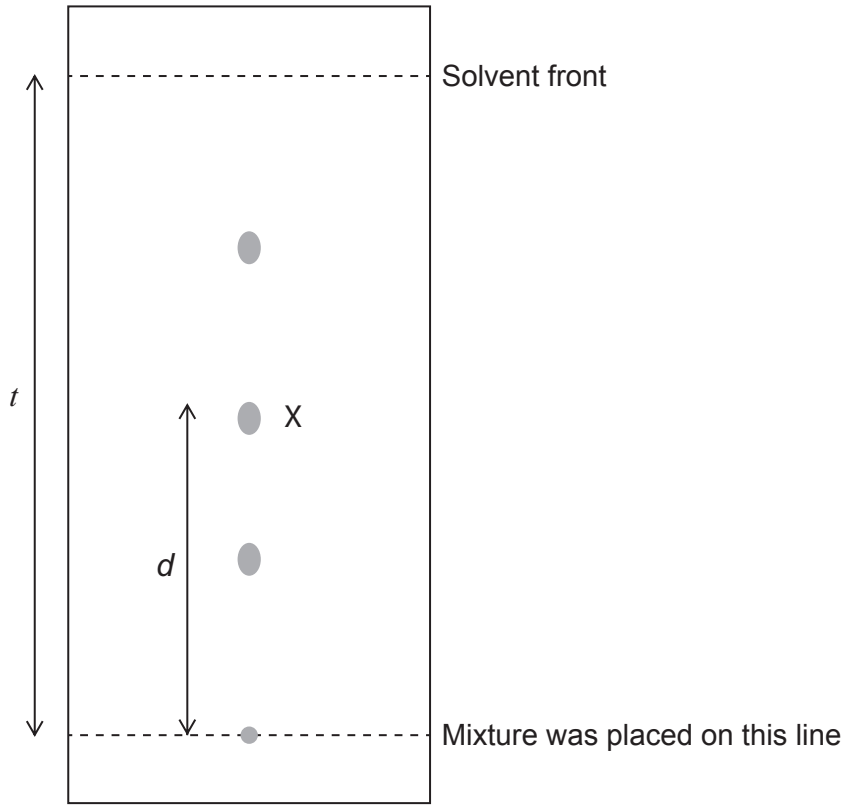
(ii) A mixture of amino acids was spotted onto chromatography paper and eluted with a solvent mixture. The following spots were seen after the paper had been developed with ninhydrin.



Determine the R_f value of the amino acid marked as X. [1]

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(Option B continues on the following page)

(Option B, question 5 continued)

(b) One protein found in the human body is collagen. Identify its function. [1]

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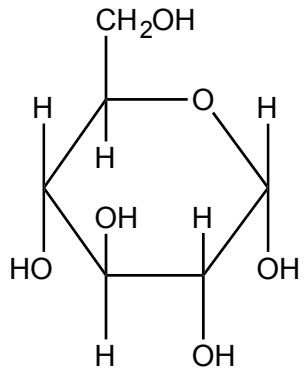
6. Glucose is an important monosaccharide for both plants and humans. Glucose molecules can combine to form polysaccharides such as amylose and cellulose.

(a) Draw a circle around the carbon atom where the structure of β-glucose differs. [1]



α-glucose

(b) (i) Compare the structures of amylose and cellulose. [2]

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. . . . . .
. . . . . .

(ii) Outline why humans cannot digest cellulose. [1]

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(Option B continues on the following page)

(Option B continued)

7. Linolenic acid (omega-3 fatty acid) is an essential fatty acid.

(a) List **two** benefits of linolenic acid to humans. [2]

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. . . . . .
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(b) (i) Define the term *iodine number*. [1]

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. . . . . .

(ii) Calculate the iodine number for linolenic acid, $C_{17}H_{29}COOH$ (M_r = 278.48). The condensed structural formula of linolenic acid is given in table 22 of the data booklet. [2]

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(Option B continues on the following page)

(Option B continued)

8. Nutrient deficiencies in a diet can be overcome by providing nutritional supplements or by increasing the nutrient content of foods.

(a) State the name of the nutritional supplement that prevents rickets. [1]

. . . . . .

(b) Suggest **two** ways of increasing the nutrient content of foods to avoid deficiency diseases. [2]

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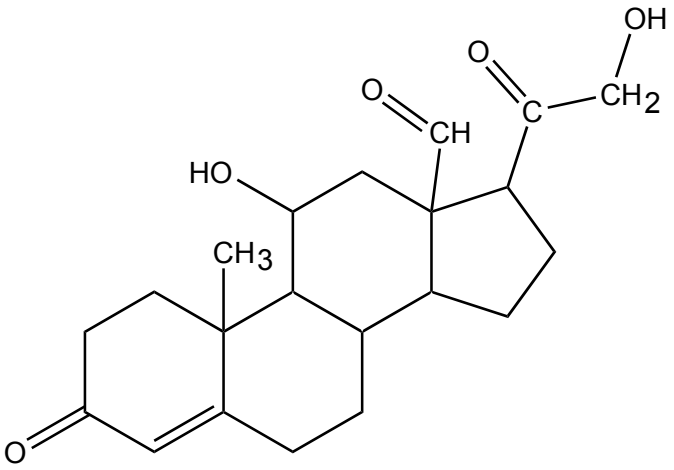
(Option B continues on the following page)

(Option B continued)

9. Cholesterol is in our diet and is produced in the body. It is used to produce steroid hormones and is important in membrane structures.

(a) Aldosterone is one of the steroid hormones produced in the body from cholesterol.



Aldosterone

The structure of cholesterol is shown in table 21 of the data booklet. Compare the structures of cholesterol and aldosterone by naming **two** functional groups present in both and **two** functional groups present only in aldosterone. [2]

Present in both:

. . . . . .

Present only in aldosterone:

. . . . . .

(b) Identify the endocrine gland which produces aldosterone. [1]

. . . . . .

. . . . . .

(Option B continues on the following page)

(Option B, question 9 continued)

(c) Progesterone and testosterone are other steroid hormones produced from cholesterol. Outline a function of progesterone or testosterone in the human body. [1]

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End of Option B

Option C — Chemistry in industry and technology

10. Iron is extracted from its ore by reduction in a blast furnace.

(a) State an equation for the reaction by which iron (III) oxide, Fe_2O_3, is reduced to iron in the blast furnace. [1]

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. . . . . .

(b) Most iron is converted to steel. Explain how alloying the steel with other metals affects its physical properties. [2]

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. . . . . .
. . . . . .

(c) Describe how quenched steel is tempered and how this changes the physical properties of the final product. [2]

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(Option C continues on the following page)

(Option C continued)

11. There has been a shift in the use of crude oil (petroleum) away from its use as an energy source and towards its use as a chemical feedstock.

(a) Suggest **two** reasons for this shift. [2]

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. . . . . .
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(b) A lot of feedstock is used in the production of plastics. Discuss **two** advantages and **one** disadvantage of using plastic for packaging instead of cardboard. [3]

Two advantages:

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. . . . . .
. . . . . .
. . . . . .
. . . . . .

One disadvantage:

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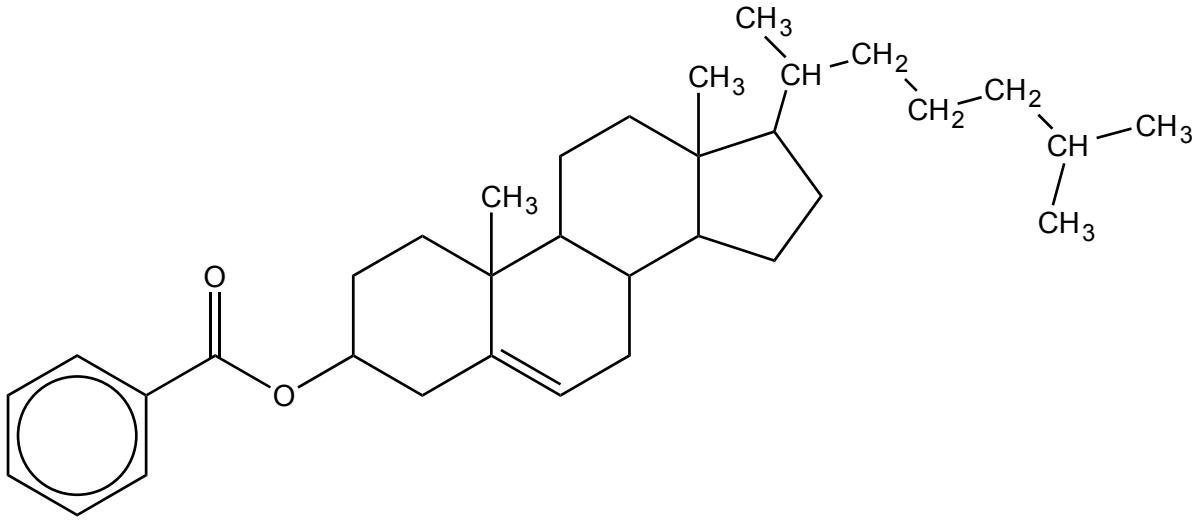
(Option C continues on the following page)

(Option C continued)

12. Cholesteryl benzoate was one of the first liquid crystals studied.



Cholesteryl benzoate

(a) Identify the structural feature of cholesteryl benzoate which makes it suitable for use as a liquid crystal. [1]

. . . . . .

(b) Suggest the essential feature a liquid-crystal molecule must have so that the display can be turned “on” and “off”. [1]

. . . . . .

(c) Outline the principles of a liquid-crystal display (LCD) device. [3]

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(Option C continues on the following page)

(Option C continued)

13. Nanotechnology has expanded in the past 30 years.

(a) Define the term *nanotechnology*. [1]

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. . . . . .

(b) Distinguish between the arrangement of carbon atoms at the sides and at the ends of carbon nanotubes. [1]

Sides:

. . . . . .

Ends:

. . . . . .

(c) Outline why bundles of carbon nanotubes have high tensile strength. [1]

. . . . . .
. . . . . .

(d) Discuss **two** concerns regarding the development of nanotechnology. [2]

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End of Option C

Option D — Medicines and drugs

14. Drug research and development is a lengthy and expensive process. Testing is required to determine the therapeutic window, tolerance and side-effects of a drug before it can be approved for use.

(a) (i) State the meaning of the term therapeutic window. [1]

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. . . . . .
. . . . . .

(ii) Suggest why a narrow therapeutic window may be a problem. [1]

. . . . . .
. . . . . .

(b) State the meaning of the term side-effects. [1]

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(c) Over-the-counter antacids have a high therapeutic window. State why some antacids contain dimethicone. [1]

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(Option D continues on the following page)

(Option D continued)

15. Morphine and its derivatives work by temporarily bonding to receptor sites in the brain, preventing the transmission of pain impulses.

(a) Discuss **one** advantage and **two** disadvantages of using morphine as an analgesic. [3]

Advantage:

. . . . . .
. . . . . .

Disadvantages:

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(b) The structures of morphine and diamorphine (heroin) are shown in table 20 of the data booklet. Describe the difference in the two structures by naming the functional groups. [1]

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(Option D continues on the following page)

(Option D continued)

16. A variety of techniques can be used to determine the ethanol concentration of the breath, blood or urine.

(a) (i) The breathalyser, one of the earliest tests, uses the reaction between ethanol and acidified potassium dichromate(VI). Ethanol is first oxidized to ethanal. Deduce the half-equation for the reaction of ethanol to ethanal. [1]

. . . . . .

(ii) Outline why the colour changes from orange to green. [1]

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. . . . . .

(b) Explain how the ethanol concentration in the breath can be measured by an intoximeter using infrared absorption. [2]

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(Option D continues on the following page)

(Option D continued)

17. Some people believe that taking the stimulants caffeine and amphetamines improves their performance in school.

(a) (i) Outline how caffeine and amphetamines may have this effect. [1]

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. . . . . .

(ii) State one adverse effect of consuming caffeine in large amounts. [1]

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. . . . . .

(b) Amphetamine and epinephrine (adrenaline) have similar structures based on phenylethylamine. The structures are shown in table 20 of the data booklet. Draw the structure of phenylethylamine. [1]

(Option D continues on the following page)

(Option D continued)

18. Diseases may be caused by bacteria or viruses.

(a) (i) Explain how penicillins work as antibacterials. [2]

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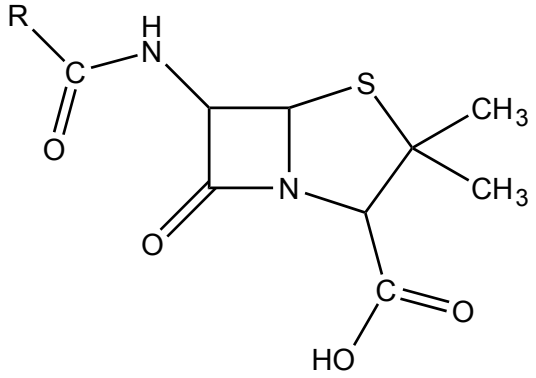
(ii) The R group in the general structure of penicillin shown below represents a side-chain which is regularly modified.



Explain why this modification is necessary. [1]

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

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End of Option D

Option E — Environmental chemistry

19. Climate change is a current global topic of debate.

(a) (i) Water and carbon dioxide are greenhouse gases present in significant quantities in the atmosphere. Identify **one** other greenhouse gas and its source. [1]

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. . . . . .

(ii) Suggest the **two** factors that influence the relative greenhouse effect of a gas. [1]

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. . . . . .

(b) Discuss **three** effects of increasing amounts of greenhouse gases in the atmosphere and their consequences. [3]

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(Option E continues on the following page)

(Option E continued)

20. Another major source of concern is the depletion of ozone in the stratosphere as a result of human activity.

(a) Describe, using equations, the formation and depletion of ozone by natural processes. [4]

Formation:

. . . . . .
. . . . . .
. . . . . .

Depletion:

. . . . . .
. . . . . .
. . . . . .

(b) Identify and state the source of **two** ozone-depleting pollutants. [2]

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(Option E continues on the following page)

(Option E continued)

21. As the world's population grows, managing waste water efficiently is as important as sources of fresh drinking water.

(a) (i) State the meaning of the term biochemical oxygen demand (BOD). [2]

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. . . . . .
. . . . . .

(ii) State the products of the anaerobic and aerobic decomposition of organic material containing the elements nitrogen or sulfur. [2]

	Nitrogen	**Sulfur**
Anaerobic	. . . . .	. . . . .
Aerobic	. . . . .	. . . . .

(b) Fresh water can be obtained from sea water by multi-stage distillation and by reverse osmosis. Explain the essential features of **one** of these processes. [3]

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(Option E continues on the following page)

(Option E, question 21 continued)

(c) A lot of non-recyclable waste is now incinerated rather than being put into landfill. Suggest **two** economic factors that need to be considered before building a new waste incineration plant. [2]

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End of Option E

Option F — Food chemistry

22. Olive oil is a complex mixture of triglycerides, some of which are derived from oleic acid.

(a) State the name of the compound which combines with fatty acids to form triglycerides. [1]

. . . . . .

(b) (i) Explain why oleic acid, *cis*-9-octadecenoic acid, has a lower melting point than its *trans* isomer, elaidic acid. [2]

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(ii) Discuss **two** effects on health of consuming *trans* fatty acids such as elaidic acid. [2]

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(iii) State **two** conditions required to hydrogenate oleic acid. [2]

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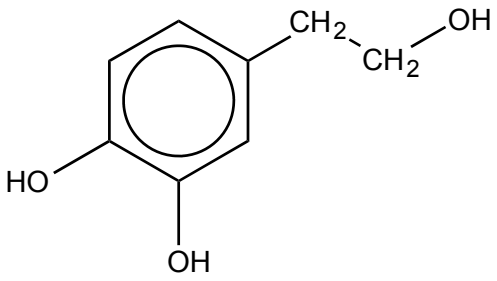
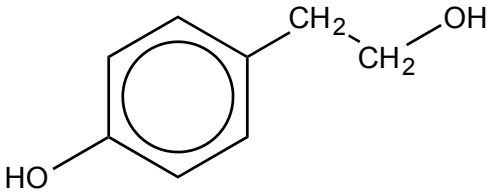
(Option F continues on the following page)

(Option F continued)

23. Olive oil contains naturally occurring antioxidants such as hydroxytyrosol, tyrosol and vitamin E.



Hydroxytyrosol



Tyrosol

(a) The structures of some synthetic antioxidants (preservatives) are shown in table 22 of the data booklet. Compare the structural features of hydroxytyrosol and tyrosol with these synthetic compounds. [3]

Similarity:

. . . . . .
. . . . . .

Differences:

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) (i) Outline how vitamin E acts as an antioxidant. [1]

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(Option F continues on the following page)

(Option F, question 23 continued)

(ii) State **two** health benefits of consuming foods containing antioxidants. [2]

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24. The colour of olive oil is due to pigments such as carotenoids.

(a) Explain why carotenoids are coloured. [2]

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(b) List **two** factors which increase the rate of oxidation of carotenoids. [2]

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(Option F continues on the following page)

(Option F continued)

25. Aioli is an emulsion containing olive oil, garlic, egg yolks and lemon juice.

(a) State how an emulsion is made. [1]

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. . . . . .

(b) Garlic and egg yolks contain phospholipids and are the emulsifiers in the aioli. Describe how the emulsifiers prevent the emulsion from separating. [2]

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End of Option F

Option G — Further organic chemistry

26. Benzene, C_6H_6, was once thought to contain alternate single and double bonds between the carbon atoms.

(a) Describe the currently accepted structure and bonding of the benzene molecule. [3]

Structure:

. . . . . .

. . . . . .

. . . . . .

Bonding:

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Outline **one** piece of thermochemical evidence that provides support for the bonds in the benzene ring **not** being alternately single and double. [1]

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(Option G continues on the following page)

(Option G continued)

27. Propene, CH_2CHCH_3, is an important monomer in the production of addition polymers. It also undergoes simple addition reactions.

(a) Explain the mechanism for the addition of hydrogen chloride, HCl, to propene that leads to the major product, using curly arrows to represent the movement of electron pairs. [4]

(b) Predict the structural formula of the organic product most likely to be formed when the reaction in (a) takes place in the presence of a high concentration of bromide ions. [1]

. . . . . .

(c) Propene may be produced from an alcohol. Applying IUPAC rules, state the name of an appropriate alcohol, the reagent used to convert it into propene and the type of reaction involved. [3]

Name of alcohol:

. . . . . .

Reagent:

. . . . . .

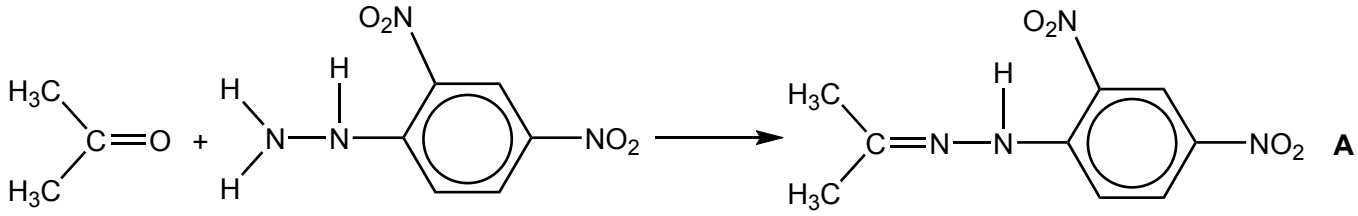
Type of reaction:

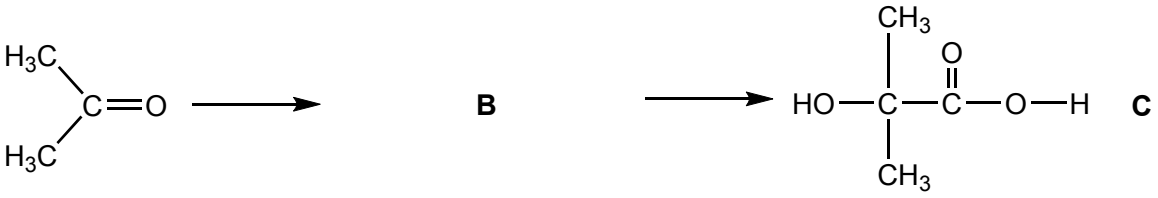
. . . . . .

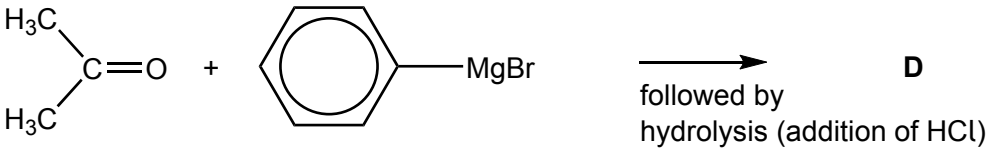
(Option G continues on the following page)

(Option G continued)

28. Carbonyl compounds such as propanone, $(CH_3)_2CO$, are very versatile starting materials for the production of other organic molecules. Consider the schemes below.







(a) Identify the type of reaction occurring in the conversion of propanone to **A**. [1]

. . . . . .

(b) (i) Deduce the structural formula of **B**. [1]

(Option G continues on the following page)

(Option G, question 28 continued)

(ii) Suggest suitable reagents for converting propanone into **B**, and **B** into **C**. [2]

Propanone into **B**:

. . . . . .

B into **C**:

. . . . . .

(iii) Explain why **C** dissociates more in aqueous solution than 2-methylpropanoic acid, $(CH_3)_2CHCOOH$. [2]

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. . . . . .
. . . . . .
. . . . . .

(c) (i) Deduce the structural formula of **D**. [1]

(ii) Identify the **two** substances that react together to produce C_6H_5MgBr. [1]

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End of Option G

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