

Chemistry

Standard level

Paper 3

Monday 16 November 2015 (morning)

Candidate session number

1 hour

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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.
- 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 |
|---|-----------|
| Option A — Modern analytical chemistry | 1 – 3 |
| Option B — Human biochemistry | 4 – 8 |
| Option C — Chemistry in industry and technology | 9 – 12 |
| Option D — Medicines and drugs | 13 – 17 |
| Option E — Environmental chemistry | 18 – 22 |
| Option F — Food chemistry | 23 – 27 |
| Option G — Further organic chemistry | 28 – 32 |



Option A — Modern analytical chemistry

1. Infrared (IR) spectroscopy is a powerful analytical technique.

(a) Describe how information from an IR spectrum can be used to identify the bonds in a molecule. [2]

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(b) Explain what happens at the molecular level during the absorption of IR radiation by water. [3]

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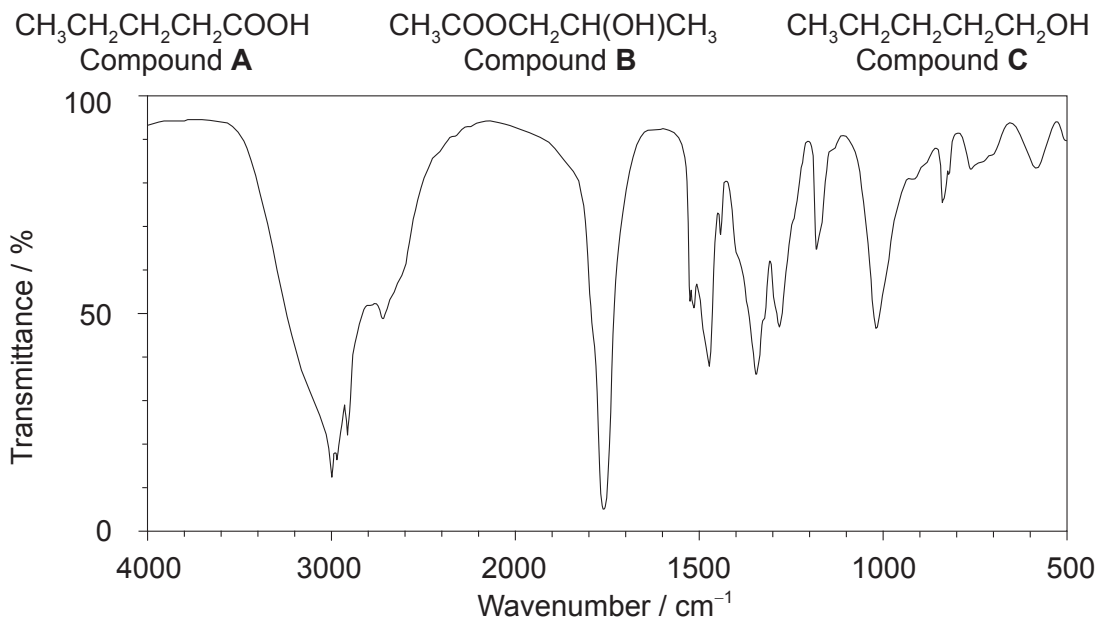
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(Option A continues on the following page)



(Option A, question 1 continued)

- (c) Explain which of the following compounds would produce the IR spectrum below by referring to the wavenumbers of the relevant peaks found in table 17 of the data booklet. [3]



[Source SDBSWeb, <http://sdb.sdb.aist.go.jp> (National Institute of Advanced Industrial Science and Technology)]

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- (d) Explain how the low resolution ^1H NMR spectra of the three compounds in part (c) can be used to distinguish between them. Ignore chemical shifts. [3]

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(Option A continues on the following page)



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(Option A, question 1 continued)

- (e) The mass spectrum of compound **A**, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH}$, shows significant peaks at mass to charge ratios of 57 and 102. Deduce the formulas of the species responsible for these peaks. [2]

$m/z = 57$:

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$m/z = 102$:

.....

2. Atomic absorption (AA) spectroscopy is used to detect very low concentrations of metal ions.

- (a) State **one** application of AA spectroscopy. [1]

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- (b) Describe the uses of the fuel and the monochromatic detector in the AA spectrophotometer. [2]

Fuel:

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Monochromatic detector:

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(Option A continues on the following page)



(Option A continued)

3. Absorption and emission spectra can be used to identify elements.

(a) Distinguish between the processes within the atom that give rise to absorption and emission spectra. [2]

Absorption spectra:

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Emission spectra:

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(b) Outline how the **emission** spectrum of a sample of gaseous element is produced. [2]

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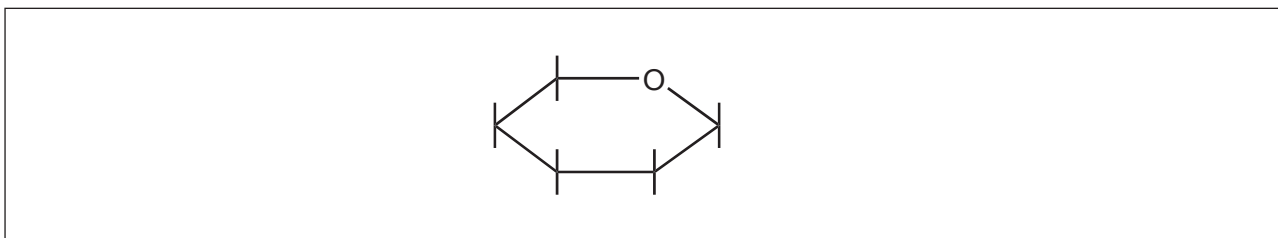
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End of Option A



Option B — Human biochemistry

4. Glucose is a carbohydrate. A skeletal structure is shown for one of the ring structures of glucose.



(a) (i) Draw the structure of β -glucose by adding the constituent atoms and groups to the diagram. [1]

(ii) State how the α -glucose would differ from the β -glucose. [1]

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(b) β -glucose polymerizes by condensation to form cellulose. State the specific type of linkage formed between the monomer units. [1]

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5. (a) Vitamins are micronutrients which are vital for good health.

Deduce the relative solubilities of vitamins C and D in water by referring to the structures shown in table 21 of the data booklet. [2]

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(Option B continues on the following page)



(Option B, question 5 continued)

- (b) The absence of micronutrients from the diet can cause significant health problems. Suggest **three** ways in which these problems could be solved.

[3]

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6. Insulin is an example of a globular protein.

- (a) The tertiary structure of insulin arises as a result of interactions between R-groups of amino acids. Outline **two** types of interaction that can occur, including in each case the atoms or groups joined together by the interaction.

[2]

| Type of interaction | Atoms or groups joined by the interaction |
|---------------------|---|
| | |
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(Option B continues on the following page)



(Option B, question 6 continued)

- (b) Lysine is one of the amino acids found in the polypeptide chain in insulin and its structure is shown in table 19 of the data booklet. It can exist in different structural forms depending on the pH of its solution.

Draw the structure of the most abundant form of lysine present under the following conditions.

[2]

At its isoelectric point:

At a pH well below its isoelectric point:

7. (a) The degree of unsaturation of a fat can be determined by finding its iodine number which is the mass of iodine, in g, reacting with 100 g of fat. An experiment determined that the iodine number for a fatty acid was 180 (M_r of the fatty acid is 280.45).

Calculate the number of C=C bonds present in a molecule of the fatty acid, showing your working.

[2]

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(Option B continues on the following page)



(Option B, question 7 continued)

- (b) Heats of combustion values for a fatty acid and sucrose were determined using a bomb calorimeter.

| Substance | Molecular formula | $\Delta H_c^\ominus / \text{kJ mol}^{-1}$ | Molar mass / g mol^{-1} |
|--------------|---|---|----------------------------------|
| Behenic acid | $\text{C}_{22}\text{H}_{44}\text{O}_2$ | -14000 | 340.58 |
| Sucrose | $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ | -5614 | 342.30 |

- (i) Calculate the energy released in kJ g^{-1} for each compound. [1]

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- (ii) Explain why there is a significant difference in the values in (b) (i). [1]

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(Option B continues on the following page)



(Option B continued)

8. Hormones are regulatory substances produced in the body.

- (a) Deduce the differences between progesterone and estradiol by naming their specific functional groups. The structures are given in table 21 of the data booklet. [2]

Two functional groups in progesterone:

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.....

Two functional groups in estradiol:

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- (b) Anabolic steroids are closely related to testosterone. State **one** medical use of anabolic steroids and **one** example of abuse of these compounds. [2]

Medical use:

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Example of abuse:

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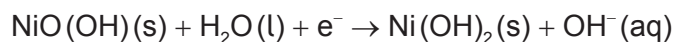
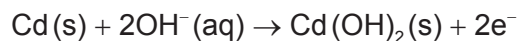
End of Option B



Option C — Chemistry in industry and technology

9. The nickel–cadmium (NiCad) battery is rechargeable.

During discharge, the following half-reactions take place:



(a) State the name of the substance used as the negative electrode (anode) during discharge and the name of the substance used as the electrolyte. [2]

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|---|
| Negative electrode (anode): Electrolyte: |
|---|

(b) When the NiCad battery is recharged, the electrodes are connected to a power supply and electrolysis occurs. State the half-equations for the chemical reactions during recharging. [1]

| |
|--|
| Negative electrode (cathode): Positive electrode (anode): |
|--|

(Option C continues on the following page)



(Option C, question 9 continued)

- (c) Compare rechargeable batteries and fuel cells. [3]

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10. Nanotechnology manipulates the properties of substances by positioning individual atoms or molecules in specific ways. Carbon nanotubes are a product of nanotechnology.

- (a) Outline how the bonding in carbon nanotubes causes them to be much stronger than graphite. [2]

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- (b) Suggest **two** health concerns that arise due to the small size of the substances used in nanotechnology. [2]

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(Option C continues on the following page)



(Option C continued)

11. Steel is formed by blowing oxygen into a mixture of iron and lime in the basic oxygen converter.

(a) State the equations for **two** reactions that occur in the basic oxygen converter. [2]

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(b) Low-carbon and high-carbon steels are produced in the basic oxygen converter. Distinguish between these two alloys in terms of their properties. [2]

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(c) The production of large amounts of slag is an environmental concern. Suggest **two** uses of slag which might reduce the environmental impact. [2]

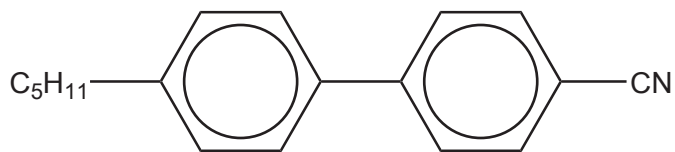
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(Option C continues on the following page)



(Option C continued)

12. Biphenyl nitriles are thermotropic liquid-crystal materials. An example of a biphenyl nitrile is shown below.



4'-pentyl-4-biphenylcarbonitrile

- (a) Distinguish between thermotropic and lyotropic liquid-crystal materials. [2]

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- (b) Explain thermotropic behaviour in terms of the arrangement of molecules. [2]

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End of Option C



Option D — Medicines and drugs

13. During the drug development process, clinical trials are carried out on humans to evaluate the effectiveness and safety of a new drug.

(a) Explain the terms therapeutic window and tolerance. [2]

Therapeutic window:

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Tolerance:

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(b) Describe one advantage and one disadvantage of taking a drug orally. [2]

Advantage:

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Disadvantage:

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(Option D continues on the following page)



(Option D continued)

14. Diamorphine is a strong analgesic which is synthesized from morphine. Both structures are given in table 20 of the data booklet.

(a) Identify the name of the functional group in morphine which is **not** present in diamorphine. [1]

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(b) Identify the type of reaction which takes place when morphine is converted to diamorphine. [1]

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(c) Explain how the function of diamorphine differs from that of mild analgesics in the relief of pain. [2]

Diamorphine:
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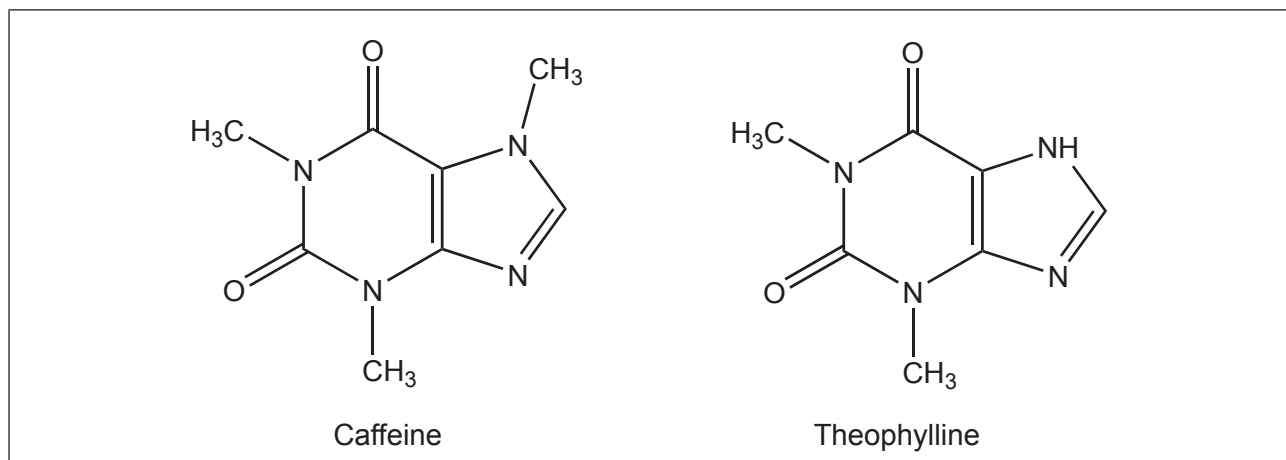
Mild analgesics:
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(Option D continues on the following page)



(Option D continued)

15. Theophylline is a stimulant closely related to caffeine and is often present in many caffeine-containing beverages.



- (a) Identify the amine group in **each** stimulant by drawing a circle around the appropriate functional group. [1]
- (b) State **two** physiological effects of stimulants. [2]

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(Option D continues on the following page)



Turn over

(Option D continued)

16. The development of new antiviral and antibacterial drugs has become a focus for the pharmaceutical industry owing to significant global health threats from infections.

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

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(b) Discuss **one** difficulty associated with developing antiviral drugs in the treatment of AIDS. [1]

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(c) Discuss **two** effects of the overuse of antibiotics. [2]

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(Option D continues on the following page)



(Option D continued)

17. Ethanol consumption by drivers causes motor vehicle accidents. The presence of ethanol in the breath may be detected by using a breathalyser containing acidified potassium dichromate(VI).

(a) State the colour change and the type of reaction occurring when the test detects ethanol.

[2]

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| Colour change: Type of reaction: |
|---|

(b) Blood ethanol levels can also be measured using an intoximeter which is either a fuel cell or an infrared (IR) spectrometer. Explain how the amount of ethanol can be determined using **one** of these techniques.

[2]

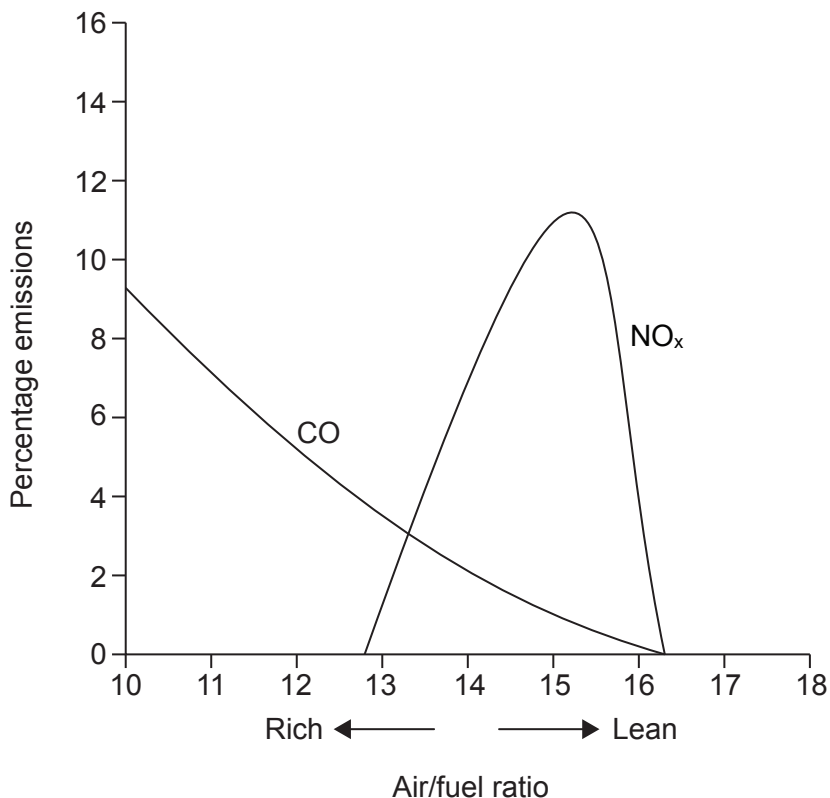
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End of Option D



Option E — Environmental chemistry

18. A car manufacturer conducted tests in which the air/fuel ratio in the engine was altered and the amounts of pollutants released measured. The results are represented below.



(a) State and explain the effect of increasing the air/fuel ratio on CO emissions. [2]

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(Option E continues on the following page)



(Option E, question 18 continued)

- (b) Explain the changes in nitrogen oxide (NO_x) emissions as the air/fuel ratio increases. [4]

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- 19.** Chlorofluorocarbons (CFCs) play an important role in the depletion of ozone in the atmosphere.

- (a) State another ozone-depleting pollutant. [1]

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- (b) Discuss one advantage and one disadvantage of using hydrofluorocarbons (HFCs) as alternatives to CFCs. [2]

Advantage:
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Disadvantage:
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(Option E continues on the following page)



(Option E continued)

20. The most commonly recycled metals are aluminium and steel.

(a) Outline **two** benefits of recycling metals. [1]

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(b) State **two** other materials that are recycled. [1]

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21. Soil degradation is an agricultural concern.

(a) Explain how soil salinization occurs. [2]

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(b) Outline how soil organic matter (SOM) can prevent soil degradation. [3]

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(Option E continues on the following page)



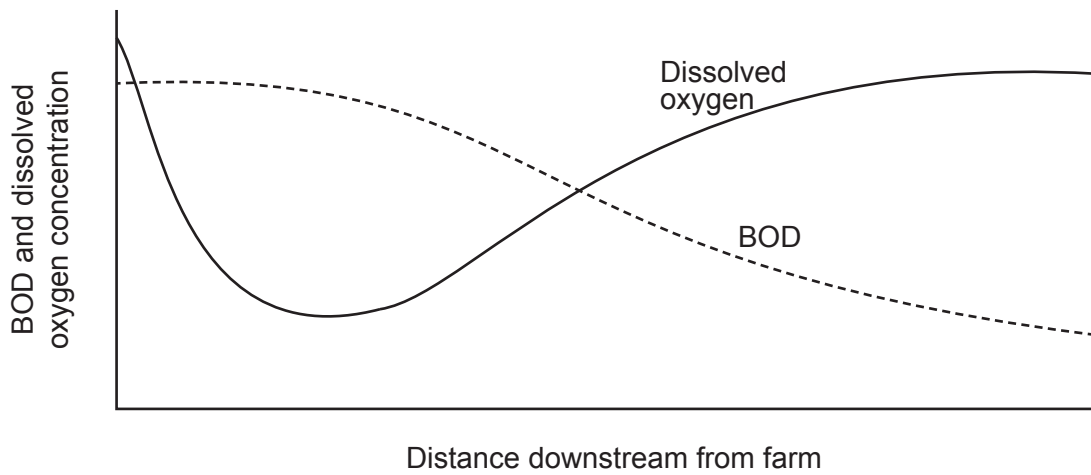
(Option E continued)

22. Biochemical oxygen demand (BOD) is a measure of oxygen-demanding wastes in water.

(a) State **two** examples of oxygen-demanding wastes. [1]

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(b) A student monitored BOD and the concentration of dissolved oxygen downstream along a river starting at a farm. Her results are represented below.



Outline the reasons for the variation in the BOD and the concentration of dissolved oxygen. [3]

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End of Option E



Option F — Food chemistry

23. Nutrients are obtained from food and are essential for maintaining a healthy body. Identify a nutrient with each given characteristic.

[3]

| Characteristic | Nutrient |
|-----------------------------|----------|
| Contains an ester group | |
| Made up of monosaccharides | |
| Essential for healthy bones | |

24. Most fats contain fatty acids which can vary in their health benefits. Some information about three fatty acids is given in the table.

| Name of fatty acid | Molecular formula | Structural formula | Melting point / °C |
|--------------------|-------------------|--------------------|--------------------|
| Stearic acid | $C_{18}H_{36}O_2$ | | 70 |
| Oleic acid | $C_{18}H_{34}O_2$ | | 13 |
| Elaidic acid | $C_{18}H_{34}O_2$ | | 44 |

(a) State the name of the unsaturated *trans* fatty acid in the table.

[1]

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(Option F continues on the following page)



(Option F, question 24 continued)

- (b) Explain why elaidic acid has a higher melting point than oleic acid. [2]

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- (c) In 2006, New York City introduced a ban on the use of *trans* fats in all its restaurants. Suggest **one** disadvantage of a diet containing *trans* fats. [1]

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25. The shelf life of a food depends on many factors.

- (a) (i) Oily fish may become rancid as the oils present contain a high proportion of polyunsaturated fatty acids. Outline how a customer would observe that food is rancid. [1]

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- (ii) State the type of rancidity that occurs in oily fish and explain how this process occurs. [3]

Type of rancidity:
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Explanation of process:
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(Option F continues on the following page)

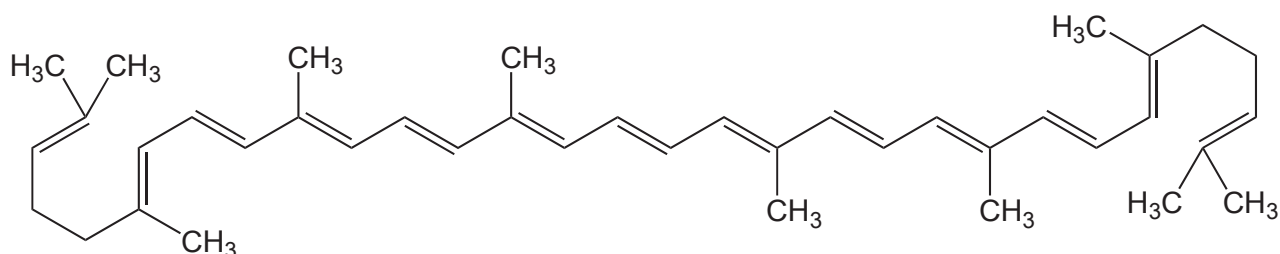


(Option F, question 25 continued)

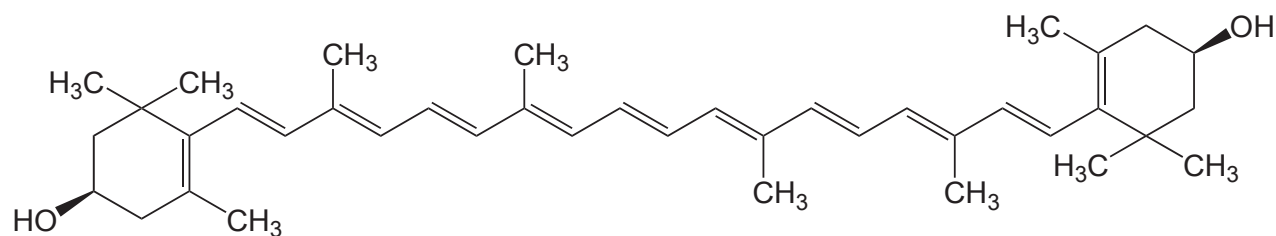
- (b) Many cheeses contain high levels of salt. Suggest why lowering the salt content may lead to a shorter shelf life. [2]

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26. Lycopene gives tomatoes their red colour and zeaxanthin gives some peppers their orange colour.



Lycopene



Zeaxanthin

- (a) Identify the class of pigments to which lycopene and zeaxanthin belong. [1]

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(Option F continues on the following page)



(Option F, question 26 continued)

- (b) (i) With reference to their interaction with light, explain why these pigments are coloured. [2]

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- (ii) State **two** factors which could affect the colour stability of lycopene and zeaxanthin. [1]

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27. Salad dressings are examples of food products which consist of stable dispersed systems.

- (a) Define the term dispersed system. [1]

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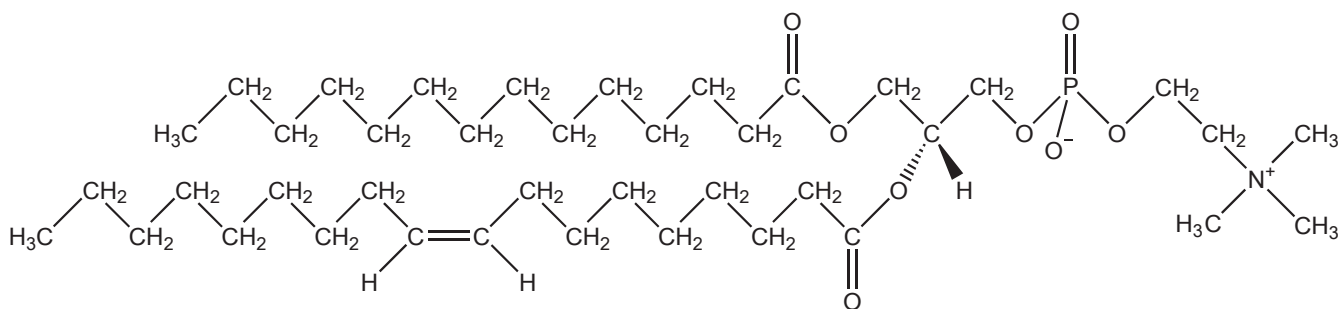
(Option F continues on the following page)



(Option F, question 27 continued)

- (b) Lecithin is an emulsifier which is an essential ingredient of salad dressings. By referring to its structure, describe the role of lecithin in salad dressings.

[2]



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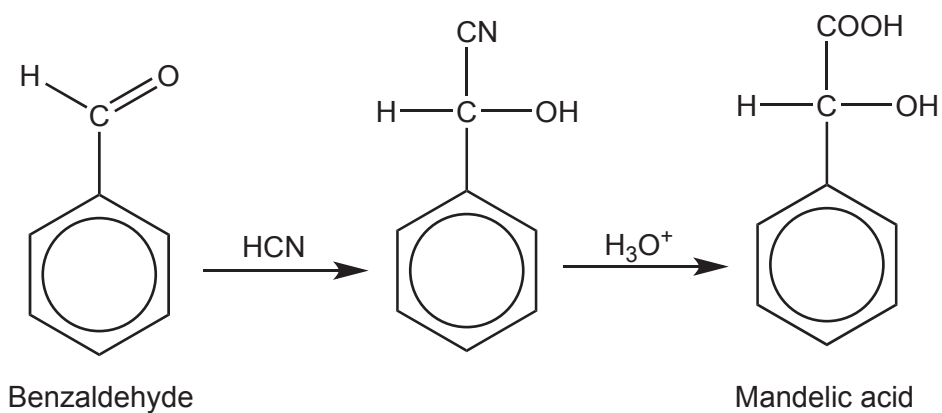
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End of Option F



Option G — Further organic chemistry

28. Mandelic acid is used in antibacterial agents. One possible route for its formation is shown below.



The first stage involves nucleophilic addition of hydrogen cyanide, HCN, to the aldehyde group in benzaldehyde.

- (a) Explain the mechanism for the reaction of benzaldehyde with HCN using curly arrows to show the movement of electron pairs. [3]

(Option G continues on the following page)



(Option G, question 28 continued)

(b) Benzaldehyde can also be used to synthesize 1-phenylethanol, $C_6H_5CH(OH)CH_3$. This reaction involves the use of a Grignard reagent.

(i) State the formula of a Grignard reagent which could be used in this reaction. [1]

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(ii) Identify the reagents and conditions for the formation of the Grignard reagent given in (b) (i). [2]

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(c) 1-phenylethanol, $C_6H_5CH(OH)CH_3$, can be converted to phenylethene, $C_6H_5CH=CH_2$, which is used in the polymer industry.

Identify the following for the conversion of 1-phenylethanol to phenylethene. [3]

Type of reaction:
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Reagent:
.....

Condition:
.....

(Option G continues on the following page)



(Option G continued)

29. 2-methylbut-2-ene, $(\text{CH}_3)_2\text{C}=\text{CHCH}_3$, reacts readily with HBr by an electrophilic addition reaction. The products are found to consist of two structural isomers with the molecular formula $\text{C}_5\text{H}_{11}\text{Br}$.

(a) Deduce the structural formula of the **major** product. [1]

(b) Explain why this isomer is the major product. [3]

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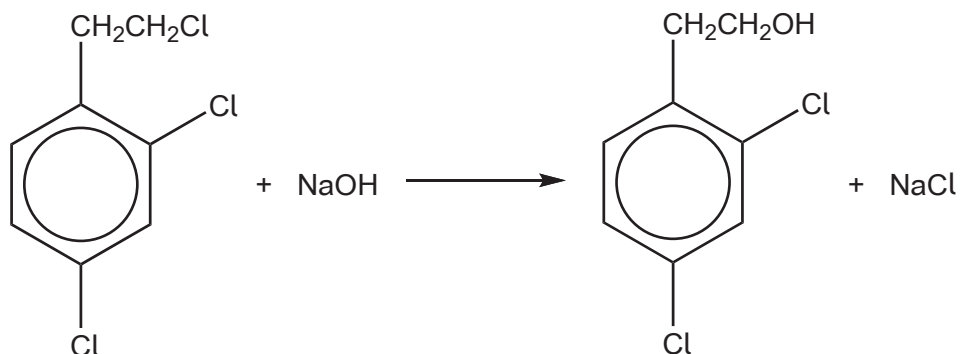
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(Option G continues on the following page)



(Option G continued)

30. A halogenated arene is reacted with warm sodium hydroxide solution as shown in the equation below.



Explain why only **one** of the three chlorine atoms is substituted by a hydroxyl group.

[2]

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(Option G continues on the following page)



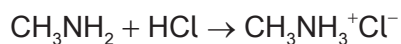
(Option G continued)

31. Methanamine, CH₃NH₂, is an organic base which is extensively used in the production of commercial organic compounds.

(a) Explain why methanamine is a stronger base than ammonia. [2]

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(b) Methanamine reacts with hydrochloric acid to form an ammonium salt.



State the name of a compound which could be used to convert this salt back to methanamine. [1]

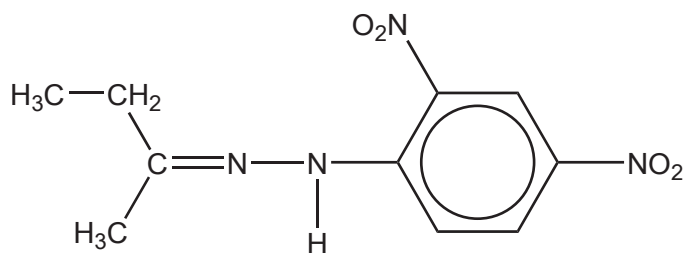
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(Option G continues on the following page)



(Option G continued)

32. A carbonyl compound, **X**, was reacted with 2,4-dinitrophenylhydrazine to form an orange crystalline precipitate. The structure of this product is shown below.



State the type of reaction occurring and identify **X**.

[2]

Type of reaction:

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Identity of **X**:

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End of Option G



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