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CHEMISTRY
STANDARD LEVEL
PAPER 3

Candidate session number

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Wednesday 9 May 2012 (morning)

1 hour

Examination code

2	2	1	2	–	6	1	1	8

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all 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 A — Modern analytical chemistry

A1. Atomic absorption (AA) spectroscopy can be used to detect very small quantities of heavy metal ions in samples of water. An analyst used AA spectroscopy to determine the concentration of cadmium and mercury ions in a sample of water taken near to a zinc mine.

(a) Outline the major change that the analyst would need to make to the spectrometer, after measuring the absorbance due to the cadmium ions, before she could measure the absorbance due to the mercury ions. *[2]*

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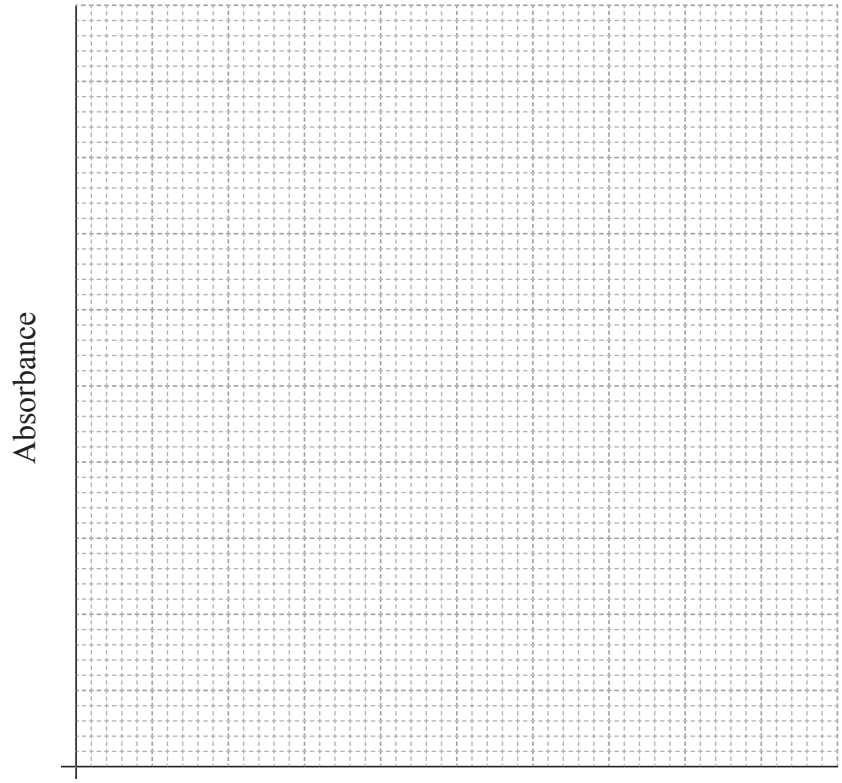
(This question continues on the following page)

(Question A1 continued)

(b) The analyst used solutions of known concentrations of cadmium to find their absorbance and also found the absorbance of the sample under the same conditions, to give the following results.

$[Cd^{2+}(aq)]$ / mg dm^{-3}	**Absorbance**
0.00	0.00
0.10	0.21
0.20	0.43
0.30	0.65
0.40	0.87
Sample with unknown concentration	0.78

Construct a calibration curve and determine the concentration of cadmium ions in the sample of water taken from near the zinc mine. *[3]*



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A2. Alumina, Al_2O_3, can be used as the stationary phase in both thin-layer chromatography (TLC) and column chromatography (CC). A solvent such as propanone can be used as the mobile phase.

(a) Explain the functions of both the stationary phase and the mobile phase in chromatography and explain their role in allowing a mixture to be separated into its individual components. *[3]*

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(b) Outline how a mixture containing two different coloured components could be separated **quantitatively** into its two pure components using column chromatography. Assume the column is packed with alumina and the mobile phase is propanone. *[4]*

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A3. (a) Deduce the number of peaks in the ^{1}HNMR spectra of 1-bromobutane and 2-bromobutane. Explain how the integration trace can be used to distinguish between the two compounds. *[3]*

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(b) Compare the ^{1}HNMR spectrum of 1-bromo-2-methylpropane with the two spectra considered in (a). Include the number of peaks and the integration trace. *[2]*

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(c) Outline the principle behind magnetic resonance imaging (MRI) used to diagnose and monitor conditions such as cancer in humans. *[3]*

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Option B — Human biochemistry

B1. (a) Outline the general function of hormones in the human body. *[1]*

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(b) Goitre is caused by the body being unable to produce sufficient amounts of a particular hormone. Identify this hormone. *[1]*

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(c) Estradiol, progesterone and testosterone are sex hormones. Their structures are given in Table 21 of the Data Booklet.

(i) State where in the body most testosterone is produced. *[1]*

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(ii) Explain, in terms of their named functional groups, how the structure of testosterone differs from the structure of progesterone. *[2]*

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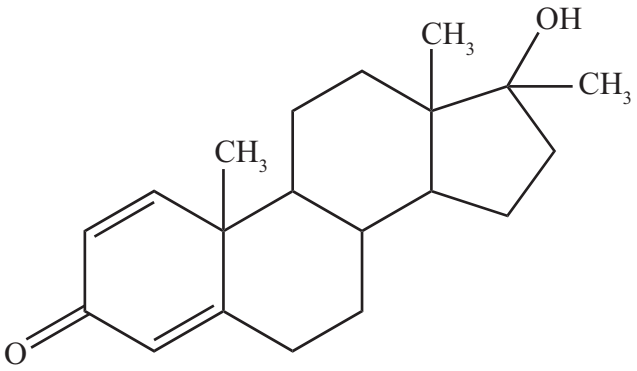
(This question continues on the following page)

(Question B1 continued)

(d) Some athletes have abused steroids in order to increase muscular strength and body mass. One such substance is dianabol (shown below) which has a structure similar to testosterone.



(i) Describe how the structure of dianabol differs from the structure of testosterone. *[1]*

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(ii) Suggest a reason why male bodybuilders who take dianabol may develop some female characteristics. *[1]*

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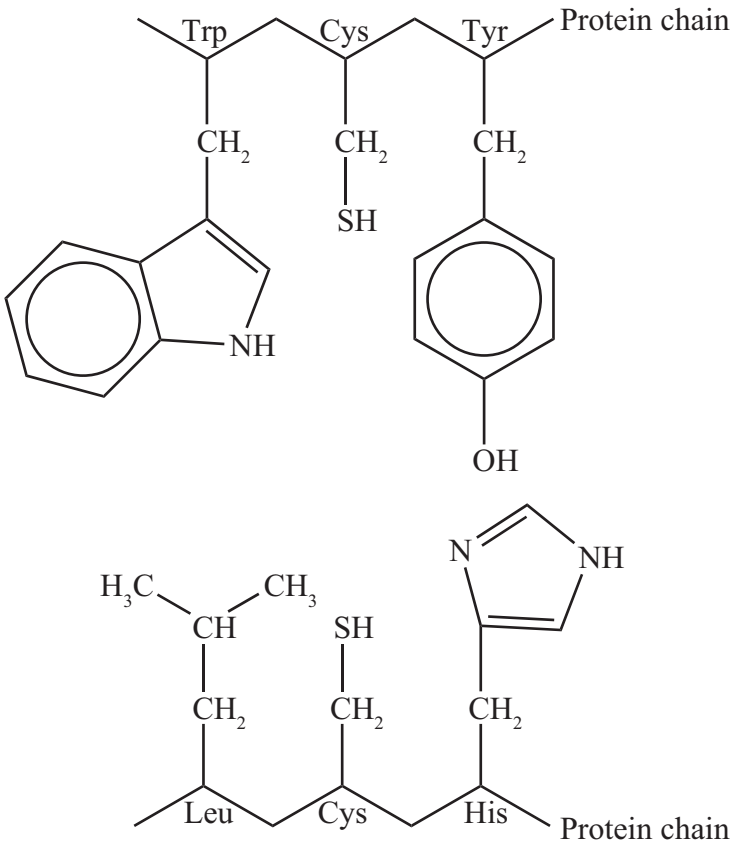
B2. (a) The primary structure of proteins describes how the different 2-amino acids are linked to each other in a linear chain. Draw the structures of the **two** different dipeptides that can be formed when alanine reacts with serine. (The structures of alanine and serine are given in Table 19 of the Data Booklet.) *[2]*

(This question continues on the following page)

(Question B2 continued)

(b) The tertiary structure of proteins describes the overall folding of the chains to give the protein its three-dimensional shape. This is caused by interactions between the side chains of distant amino acid residues. Consider the following two segments of a polypeptide chain.



(i) Deduce the type of interaction that can occur between the side chains of Trp and Leu, Cys and Cys, and Tyr and His. *[3]*

Trp and Leu: . . . . . .

Cys and Cys: . . . . . .

Tyr and His: . . . . . .

(This question continues on the following page)

(Question B2 continued)

(ii) State the name of **one** other type of interaction that can occur between the side chains of amino acid residues. *[1]*

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(c) Describe the *quaternary structure* of proteins. *[1]*

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B3. (a) Low-density lipoproteins (LDL) can cause cholesterol to line the walls of the arteries and lead to cardiovascular disease. High-density lipoproteins (HDL) are smaller than low-density lipoproteins.

(i) Identify the major source of low-density lipoproteins. *[1]*

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(ii) State the importance of high-density lipoproteins. *[1]*

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(This question continues on the following page)

(Question B3 continued)

(b) The formulas of linoleic acid and linolenic acid are given in Table 22 of the Data Booklet. Many vegetable oils are advertised as being a good source of omega-6 fatty acids whereas green leaves are a good source of omega-3 fatty acids.

(i) Compare the chemical structures of linoleic acid, an omega-6 fatty acid, and linolenic acid, an omega-3 fatty acid. *[3]*

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(ii) Linoleic acid and linolenic acid are described as essential fatty acids. State the meaning of the term *essential*. *[1]*

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Option C — Chemistry in industry and technology

C1. (a) The pig iron produced in a blast furnace contains 4–5 % carbon and smaller amounts of other elements such as phosphorus and silicon. It can be converted into steel using an oxygen converter.

(i) Other than pig iron, oxygen, and different transition metals, list **two** other substances that are added to the basic oxygen converter. *[2]*

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(ii) Explain how the phosphorus and silicon are removed. *[2]*

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(b) Steel is an alloy of iron, carbon and other metallic and non-metallic elements. Stainless steel contains about 18 % chromium and 8 % nickel. Explain why iron can form alloys with other transition metals. *[2]*

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(This question continues on the following page)

(Question C1 continued)

(c) The properties of alloys can be altered by heat treatment. Describe the process of annealing and state how this affects the properties of steel. *[2]*

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C2. (a) A fuel cell can be made using an electrolyte of aqueous sodium hydroxide with porous electrodes which allow the passage of water, hydrogen and oxygen. State the equations for the reactions that occur at the positive and negative electrodes. *[2]*

(+) electrode (cathode):

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(–) electrode (anode):

. . . . . .

(b) Electricity can also be generated from a lead–acid storage battery. The electrolyte is a solution of sulfuric acid and the electrodes are made of lead and lead(IV) oxide. State the equations for the reactions that occur at the positive and negative electrodes. *[2]*

(+) electrode (cathode):

. . . . . .

(–) electrode (anode):

. . . . . .

(c) Lead–acid batteries are heavy. Much lighter rechargeable cells are nickel–cadmium batteries used in electronic equipment.

(i) Explain why fuel cells are less damaging to the environment than nickel–cadmium batteries. *[1]*

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(This question continues on the following page)

(Question C2 continued)

(ii) Other than cost, state **one** major difference between fuel cells and nickel–cadmium cells. *[1]*

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C3. (a) Ethene can be polymerized to form high-density poly(ethene), HDPE, or low-density poly(ethene), LDPE, depending on the reaction conditions. Describe the main structural difference between HDPE and LDPE and explain how this accounts for their different properties. *[3]*

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(b) (i) The repeating unit of poly(propene) has the formula:

$$-[-CH_2-CH(CH_3)-]-$$

Draw a section of the polymer containing **five** repeating units to illustrate atactic poly(propene). *[1]*

(ii) Explain why isotactic poly(propene) is tough and can be used to make car bumpers (fenders), whereas atactic poly(propene) is soft and flexible making it suitable for sealants. *[2]*

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Option D — Medicines and drugs

D1. A well-known brand of antacids contains 0.160 g of aluminium hydroxide and 0.105 g of magnesium carbonate in each tablet.

(a) State the separate equations for the reactions of aluminium hydroxide and magnesium carbonate with hydrochloric acid. *[2]*

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(b) Determine which of the two components of the tablet will neutralize the most acid. *[2]*

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(c) The tablets also contain alginic acid and sodium hydrogencarbonate. The function of the sodium hydrogencarbonate is to react with the alginic acid to form sodium alginate. State the function of the sodium alginate produced. *[1]*

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(d) On the leaflet which comes with the tablets it states that one of the side effects of the tablets is belching. Explain why this might occur. *[1]*

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D2. Amphetamine is a stimulant and is known as a sympathomimetic drug. It has a structure with some similarities to epinephrine (adrenaline). The structures of both substances are given in Table 20 of the Data Booklet.

(a) Explain the meaning of the term *sympathomimetic*. *[1]*

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(b) Amphetamine and epinephrine both derive from the phenylethylamine structure. Draw the structure of phenylethylamine. *[1]*

(c) Compare the two nitrogen containing groups in amphetamine and epinephrine. *[2]*

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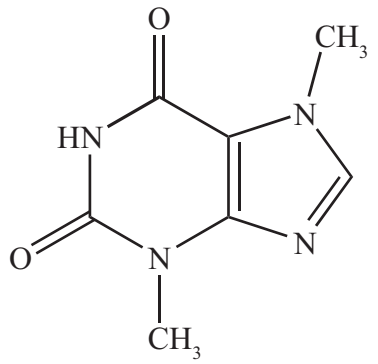
(This question continues on the following page)

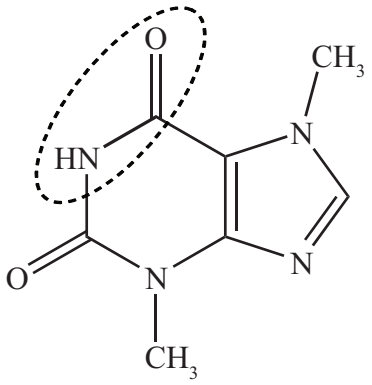
(Question D2 continued)

(d) Caffeine is also a stimulant. Caffeine is found in chocolate along with another stimulant called theobromine (shown below).



(i) Identify the alkene group in theobromine (above) by drawing a ring around it. *[1]*

(ii) State the name of the functional group in theobromine circled below. *[1]*



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(iii) State the name and classification of the N–CH_3 group in the **five**-membered ring. *[1]*

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D3. The discovery of penicillin by Alexander Fleming in 1928 is often given as an example of serendipity in science.

(a) Describe the chance event that led to Alexander Fleming's discovery of penicillin. *[1]*

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(b) Outline the work of Florey and Chain in developing penicillin. *[3]*

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(c) Explain how penicillin works and why it is necessary to continue to develop new forms of penicillin with modified side chains. *[3]*

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Option E — Environmental chemistry

E1. Catalytic converters are fitted to cars to convert polluting exhaust gases into less harmful gases.

(a) Describe how the combustion of petrol (gasoline) in an internal combustion engine produces carbon monoxide and oxides of nitrogen. *[2]*

Carbon monoxide:

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Oxides of nitrogen:

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(b) Other than carbon monoxide, carbon dioxide, and oxides of nitrogen, state **one** other pollutant gas emitted from an internal combustion engine. *[1]*

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(c) Identify **one** substance used as the catalyst in a catalytic converter and deduce the equation for the reaction that occurs between carbon monoxide and nitrogen(II) oxide inside the catalytic converter. *[3]*

Substance:

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Equation:

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(This question continues on the following page)

(Question E1 continued)

(d) Evaluate the effects of changing the fuel/air ratio in the internal combustion engine. *[2]*

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E2. Discuss soil pollution, nutrient depletion and salinization as causes of soil degradation. In each case explain the reason for the cause and how it degrades the soil. *[6]*

Soil pollution:

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Nutrient depletion:

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Salinization:

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E3. (a) Biochemical oxygen demand (BOD) can be used to measure the amount of pollution in river water. Outline what is meant by *BOD*. *[2]*

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(b) State the main product formed by phosphorus in organic material when it decays aerobically and anaerobically. *[2]*

Aerobic decomposition:

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Anaerobic decomposition:

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(c) The main use of water in industry is as a coolant. Describe how fish may be affected if heated water is discharged into a river. *[2]*

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Option F — Food chemistry

F1. Some foods contain natural antioxidants which help to prolong their shelf life.

(a) Explain the meaning of the term *shelf life*. *[1]*

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(b) The shelf life of oily fish decreases upon exposure to light.

(i) Identify the chemical feature in the oil in fish that is susceptible to photo-oxidation. *[1]*

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(ii) State the specific term given to food that is unsuitable for eating as a result of photo-oxidation. *[1]*

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(iii) Suggest how light initiates this process. *[1]*

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(This question continues on the following page)

(Question F1 continued)

(c) The compound 3-BHA is a synthetic antioxidant which is added to some foods. The structure of 3-BHA is given in Table 22 of the Data Booklet. Identify **two** features from its structure that are responsible for its antioxidant properties. *[2]*

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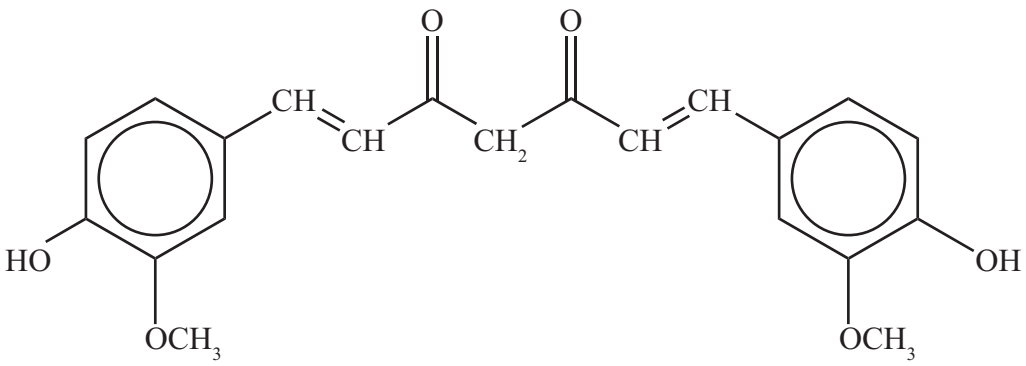
(d) Some foods contain a yellow spice called turmeric. The active ingredient in turmeric is curcumin, shown below.



Suggest which structural feature of curcumin is responsible for extending the shelf life of such a food. *[1]*

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F2. Fats and oils have some similarities and some differences in their chemical structures.

(a) State **two** major differences in their structures. *[2]*

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(b) Describe how an oil can be converted into a fat. *[2]*

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(c) Discuss **two** advantages and **two** disadvantages of converting oils into fats. *[4]*

Advantages:

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Disadvantages:

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F3. (a) State **one** essential property of an emulsifier. *[1]*

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(b) Egg yolks contain a natural emulsifier. Outline why many recipes insist on beating or whisking when making foods containing eggs. *[1]*

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(c) State the purpose of stabilizers when they are added to emulsions. *[1]*

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(d) Food additives, such as emulsifiers and synthetic colourants, are given E numbers in some countries to identify them while other countries use an International Numbering System (INS). Discuss the safety issues associated with the use of synthetic colourings in food. *[2]*

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Option G — Further organic chemistry

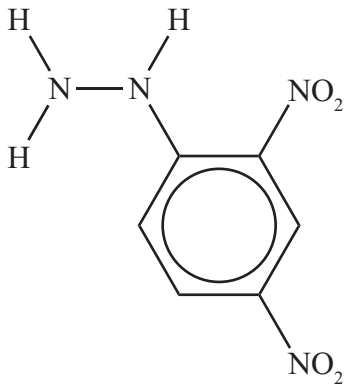
G1. Propan-2-ol is a secondary alcohol. It can undergo both elimination and oxidation reactions.

(a) In the presence of an acid catalyst, propan-2-ol can react to give an alkene. Explain the mechanism of this reaction using curly arrows to represent the movement of electron pairs. *[4]*

(This question continues on the following page)

(Question G1 continued)

(b) Propan-2-ol can be oxidized by an acidified solution of potassium dichromate(VI) to give propanone. This product can be identified by reacting it with 2,4-dinitrophenylhydrazine (shown below) to give a crystalline solid with a characteristic melting point.



(i) State the type of reaction taking place when propanone reacts with 2,4-dinitrophenylhydrazine. *[1]*

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(ii) State the structural formula of the organic compound formed when propanone reacts with 2,4-dinitrophenylhydrazine. *[1]*

G2. The number of carbon atoms in a ketone can be increased by reacting it with hydrogen cyanide.

(a) State the name given to the type of reaction taking place when propanone reacts with hydrogen cyanide. *[1]*

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

(c) State how the product from the above reaction can be converted into 2-hydroxy-2-methylpropanoic acid. *[1]*

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(This question continues on the following page)

(Question G2 continued)

(d) The number of carbon atoms in organic molecules can also be increased using Grignard reagents.

(i) State the formula of the product, **X**, formed from the reaction of bromopropane with magnesium metal. *[1]*

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(ii) State the structural formula of the organic product formed when **X** reacts with propanone followed by water. *[1]*

G3. The non-bonding pair of electrons on the nitrogen atom in amines is responsible for their basic properties.

(a) Explain why methylamine, CH_3NH_2, is a stronger base than ammonia, NH_3. *[2]*

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(b) Explain why diethylamine is a stronger base than ethylamine. *[1]*

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(c) 1-aminopentane, $CH_3CH_2CH_2CH_2CH_2NH_2$, contains a polar amine group. Explain why it is not very soluble in water but is very soluble in dilute hydrochloric acid. *[2]*

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(d) State the equation for the reaction of methylammonium chloride, CH_3NH_3Cl, with sodium hydroxide. *[1]*

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