Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 3

Friday 12 May 2017 (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.
- Answers must be written within the answer 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 **[35 marks]**.

Section A	Questions
Answer all questions.	1 – 2

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Materials	3 – 6
Option B — Biochemistry	7 – 11
Option C — Energy	12 – 14
Option D — Medicinal chemistry	15 – 19

2217 – 6118

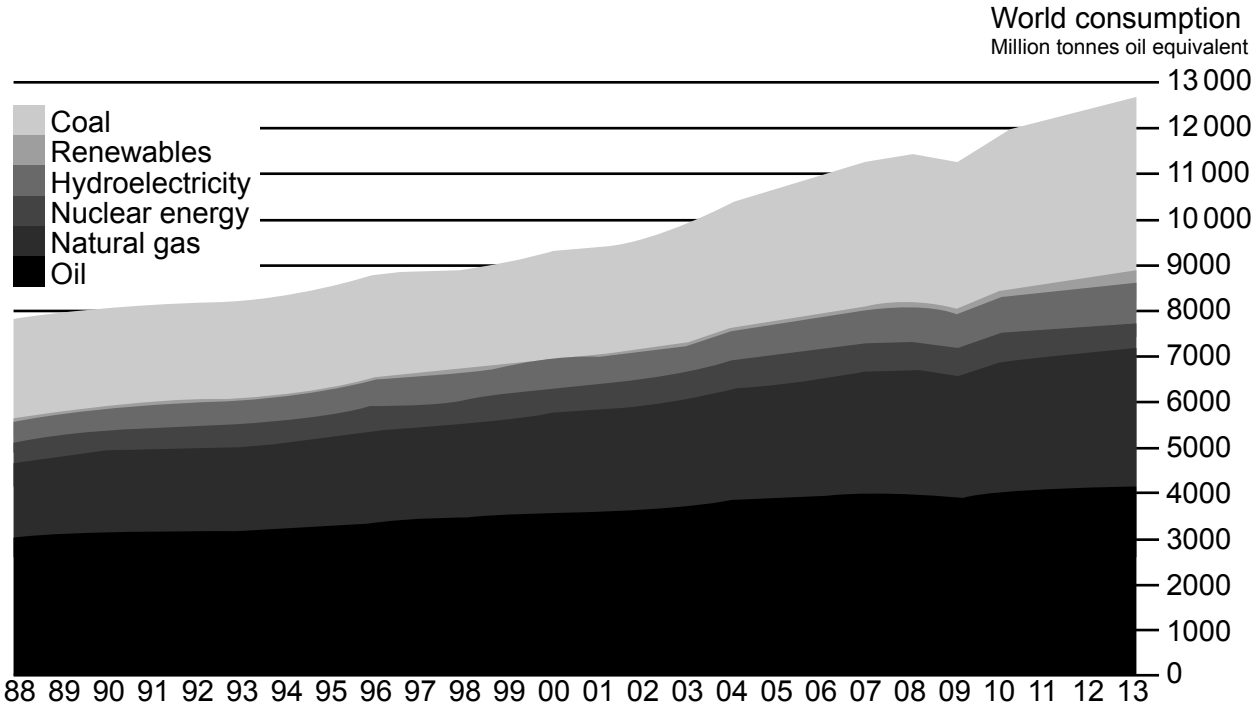
24 pages

Section A

Answer **all** questions. Write your answers in the boxes provided.

1. There is a link between world energy consumption and carbon dioxide production.

(a) The following graph represents world energy consumption by type for the years 1988–2013.



[Source: BP statistical review of world energy, www.bp.com]

Estimate the percentage of energy consumption which did **not** directly produce CO_2 in 2013. [1]

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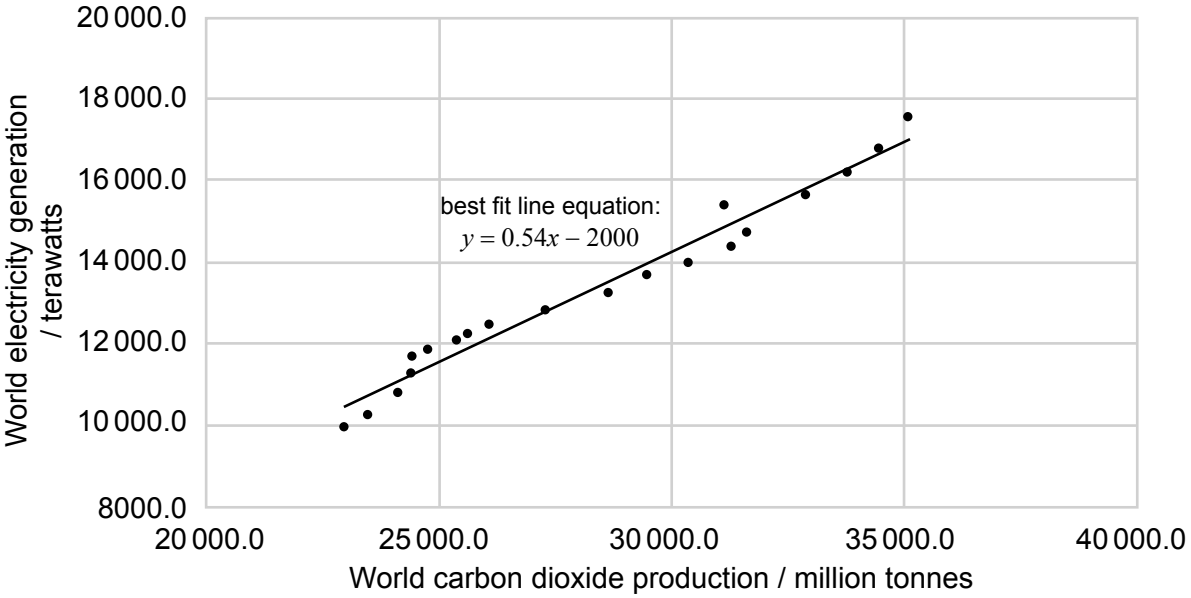
(This question continues on the following page)

(Question 1 continued)

(b) O_2 is consumed in producing CO_2 for electricity generation. The graph shows the relationship between the world's electricity generation and CO_2 production between 1994 and 2013.



[Source: BP statistical review of world energy, www.bp.com]

Calculate the mass, in million tonnes, of oxygen gas ultimately found in CO_2 which is consumed in generating 18 000 terawatts of electricity using the equation given for the best fit line. Give your answer to 2 significant figures.
Assume coal is the only energy source. [2]

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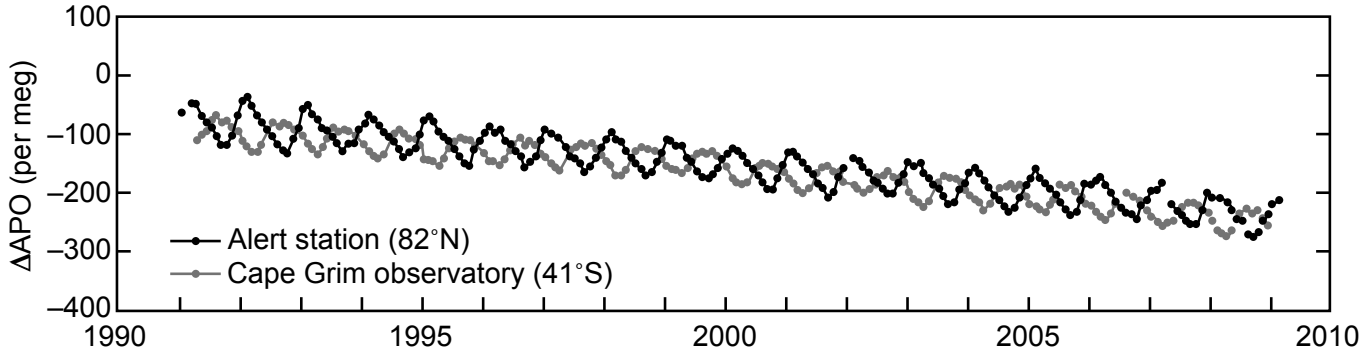
(This question continues on the following page)

(Question 1 continued)

(c) Climate induced changes in the ocean can be studied using measurements such as the Atmospheric Potential Oxygen (APO). Trends in APO concentration from two stations, one in each hemisphere, are shown below.



Trends in atmospheric potential oxygen (APO) based on monthly averages between 1990 and 2010.

[Source: www.ioos.noaa.gov]

(i) The equilibrium expression for O_2 exchange between the atmosphere and ocean is $O_2(g) \rightleftharpoons O_2(aq)$. Identify **one** factor which shifts the equilibrium to the right. [1]

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(ii) Factors such as photosynthesis and respiration are excluded so that APO is influenced by oceanic changes only. Suggest why the seasonal cycles from Alert station and Cape Grim observatory are different. [2]

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(This question continues on the following page)

(Question 1 continued)

(iii) The change in APO O_2/N_2 ratio, per meg, is measured relative to an O_2/N_2 reference.

$$\Delta(O_2/N_2) = \left(\frac{(O_2/N_2)_{sample}}{(O_2/N_2)_{reference}} - 1 \right) \times 10^6$$

Calculate the APO $\Delta(O_2/N_2)$ value for an oxygen concentration of 209 400 ppm assuming that any change in N_2 concentration is negligible. Reference values for O_2 and N_2 are 209 460 and 790 190 ppm respectively. [1]

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(iv) Suggest a reason for the general negative gradient of the APO curve given in (c). [1]

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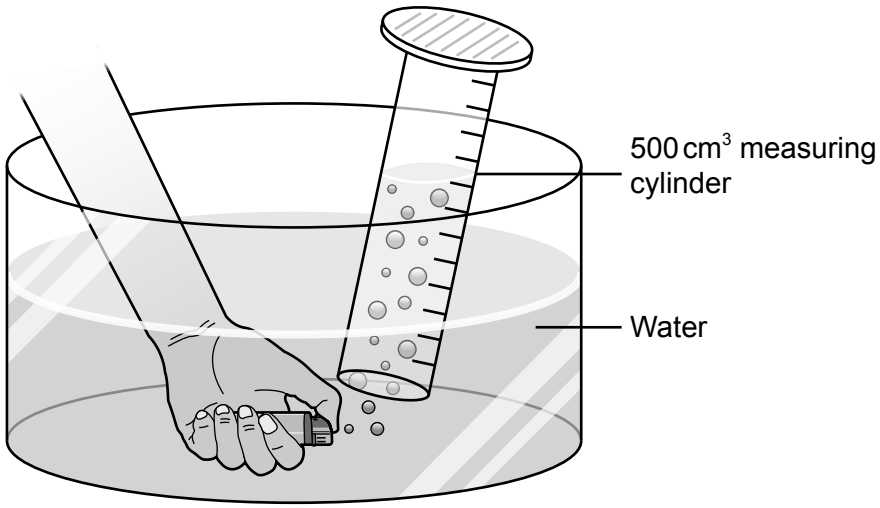
2. Disposable plastic lighters contain butane gas. In order to determine the molar mass of butane, the gas can be collected over water as illustrated below:



(a) List the data the student would need to collect in this experiment. [4]

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(b) (i) Explain why this experiment might give a low result for the molar mass of butane. [2]

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(ii) Suggest **one** improvement to the investigation. [1]

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Section B

Answer **all** of the questions from **one** of the options. Write your answers in the boxes provided.

Option A — Materials

3. Polymer nanocomposites often have better structural performance than conventional materials. Lithographic etching and metal coordination are two methods of assembling these nanocomposites.

(a) State the two distinct phases of a composite. [2]

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(b) Identify the methods of assembling nanocomposites by completing the table. [2]

	Physical or chemical	Bottom up or top down
Lithography	. . . . .	. . . . .
Metal coordination	. . . . .	. . . . .

(c) Nanoparticles anchor plasticizers in PVC so that they cannot escape from the polymer as easily.

(i) Explain how the structure of plasticizers enables them to soften PVC. [3]

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(ii) Suggest a reason why nanoparticles can better anchor plasticizers in the polymer. [1]

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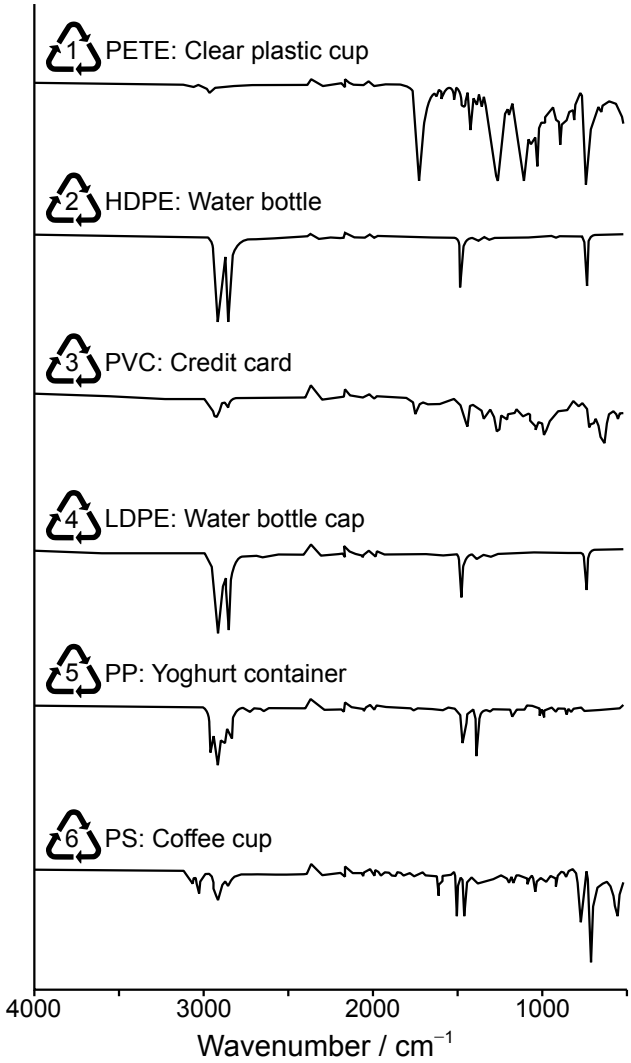
(Option A continues on the following page)

(Option A continued)

4. Infrared (IR) spectra can be used to distinguish between various types of plastics. Some simplified IR spectra are given here.



[Source: M Rozov, TK Valdez, L Valdez and RK Upmacis, (2013), "Teaching Green Chemistry Principles to Undergraduate Students", *Athens Journal of Sciences*]

Explain, with a reference to molecular structure, which two of the plastics can **not** be distinguished by IR spectroscopy. [2]

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(Option A continues on the following page)

(Option A continued)

5. Rhodium and palladium are often used together in catalytic converters. Rhodium is a good reduction catalyst whereas palladium is a good oxidation catalyst.

(a) In a catalytic converter, carbon monoxide is converted to carbon dioxide. Outline the process for this conversion referring to the metal used. [3]

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(b) (i) Nickel is also used as a catalyst. It is processed from an ore until nickel(II) chloride solution is obtained. Identify **one** metal, using sections 24 and 25 of the data booklet, which will not react with water and can be used to extract nickel from the solution. [1]

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(ii) Deduce the redox equation for the reaction of nickel(II) chloride solution with the metal identified in (b)(i). [1]

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(c) Another method of obtaining nickel is by electrolysis of a nickel(II) chloride solution. Calculate the mass of nickel, in g, obtained by passing a current of 2.50 A through the solution for exactly 1 hour. Charge (Q) = current (I) × time (t). [2]

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(Option A continues on the following page)

(Option A continued)

6. Liquid Crystal on Silicon, LCoS, uses liquid crystals to control pixel brightness. The degree of rotation of plane polarized light is controlled by the voltage received from the silicon chip.

(a) Two important properties of a liquid crystal molecule are being a polar molecule and having a long alkyl chain. Explain why these are essential components of a liquid crystal molecule. [2]

Polar molecule:

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Long alkyl chain:

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(b) Metal impurities during the production of LCoS can be analysed using ICP-MS. Each metal has a detection limit below which the uncertainty of data is too high to be valid. Suggest **one** factor which might influence a detection limit in ICP-MS/ICP-OES. [1]

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End of Option A

Option B — Biochemistry

7. The structures of the amino acids cysteine, glutamine and lysine are given in section 33 of the data booklet.

(a) Deduce the structural formula of the dipeptide Cys-Lys. [2]

(b) Identify the type of bond between two cysteine residues in the tertiary structure of a protein. [1]

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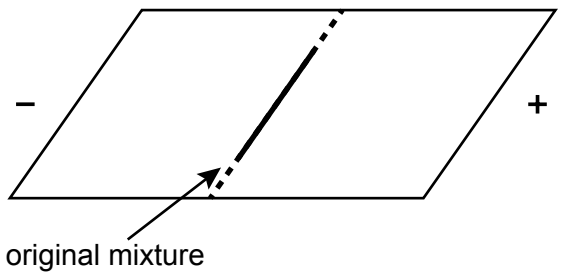
(c) Deduce the structural formula of the predominant form of cysteine at pH 1.0. [1]

(d) A mixture of the three amino acids, cysteine, glutamine and lysine, was placed in the centre of a square plate covered in polyacrylamide gel. The gel was saturated with a buffer solution of pH 6.0. Electrodes were connected to opposite sides of the gel and a potential difference was applied.

Sketch lines on the diagram to show the relative positions of the three amino acids after electrophoresis. [2]



(Option B continues on the following page)

(Option B continued)

8. Sunflower oil contains stearic, oleic and linoleic fatty acids. The structural formulas of these acids are given in section 34 of the data booklet.

(a) Explain which one of these fatty acids has the highest boiling point. [2]

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(b) 10.0 g of sunflower oil reacts completely with 123 cm^3 of 0.500 mol dm^{-3} iodine solution. Calculate the iodine number of sunflower oil to the nearest whole number. [3]

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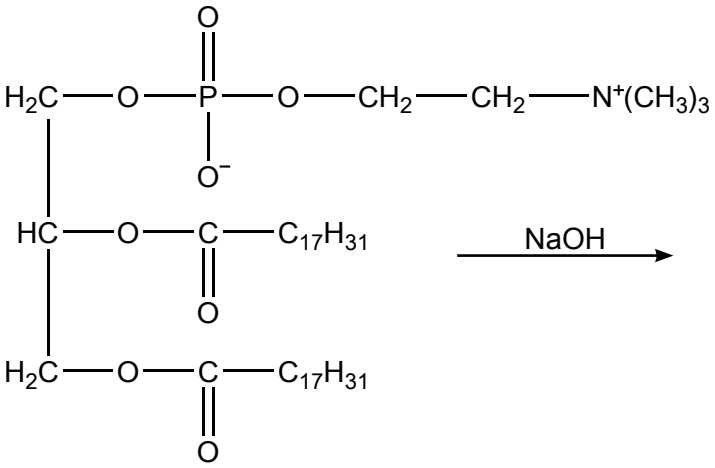
(Option B continues on the following page)

(Option B continued)

9. A chemical reaction occurs when a phospholipid is heated with excess sodium hydroxide.



(a) Glycerol is one product of the reaction. Identify the two other organic products. [2]

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(b) Identify the type of reaction which occurs. [1]

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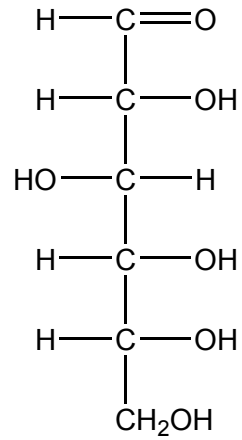
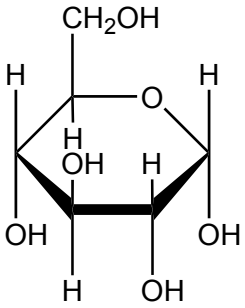
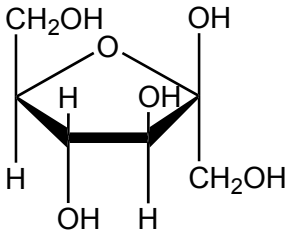
(Option B continues on the following page)

(Option B continued)

10. Monosaccharides can combine to form disaccharides and polysaccharides.


straight chain glucose


α-glucose


β-fructose

(a) Identify the functional groups which are present in only one structure of glucose. [2]

Only in straight chain form:

. . . . . .

Only in ring structure:

. . . . . .

(b) Sucrose is a disaccharide formed from α-glucose and β-fructose.
Deduce the structural formula of sucrose. [1]

(Option B continues on the following page)

(Option B, question 10 continued)

(c) Starch is a constituent of many plastics. Suggest **one** reason for including starch in plastics. [1]

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(d) Suggest **one** of the challenges scientists face when scaling up the synthesis of a new compound. [1]

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11. Suggest, in terms of its structure, why vitamin D is fat-soluble using section 35 of the data booklet. [1]

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End of Option B

Option C — Energy

12. The sun is the main source of energy used on earth.

(a) (i) One fusion reaction occurring in the sun is the fusion of deuterium, $^{2}_{1}H$, with tritium, $^{3}_{1}H$, to form helium, $^{4}_{2}He$. State a nuclear equation for this reaction. [1]

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(ii) Explain why this fusion reaction releases energy by using section 36 of the data booklet. [2]

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(iii) State the technique used to show that the sun is mainly composed of hydrogen and helium. [1]

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(b) Coloured molecules absorb sunlight. Identify the bonding characteristics of such molecules. [1]

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(Option C continues on the following page)

(Option C continued)

13. There are many sources of energy available.

(a) State **one** advantage and **one** disadvantage for each energy source in the table. [4]

Energy Source	Advantage	Disadvantage
Biofuels	. . . .	. . . .
Fossil fuels	. . . .	. . . .

(b) (i) Calculate the specific energy of hydrogen, stating its units. Refer to sections 1, 6 and 13 of the data booklet. [2]

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(ii) Hydrogen has a higher specific energy than petrol (gasoline) but is not used as a primary fuel source in cars. Discuss the disadvantages of using hydrogen. [2]

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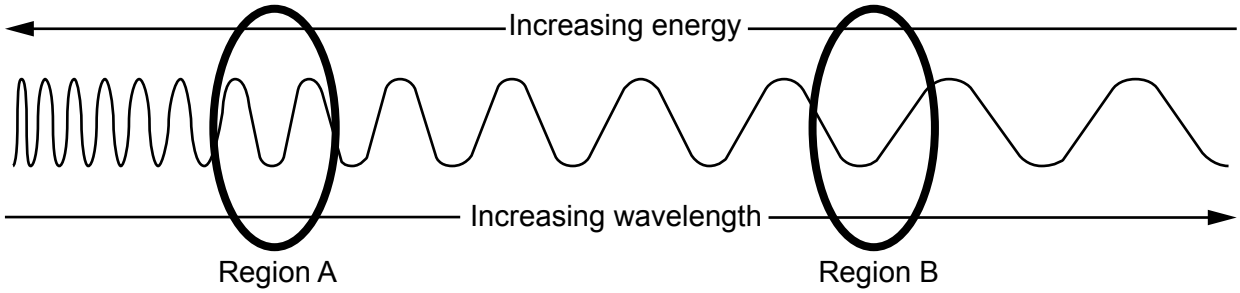
(Option C continues on the following page)

(Option C continued)

14. The combustion of fossil fuels produces large amounts of CO_2, a greenhouse gas.
The diagram below illustrates a range of wavelengths in the electromagnetic spectrum.



(a) Identify which region, **A** or **B**, corresponds to each type of radiation by completing the table. [1]

Type of radiation	Region
Incoming radiation from sun	. . . . .
Re-radiated from Earth's surface	. . . . .
Absorbed by CO_2 in the atmosphere	. . . . .

(b) (i) Oceans can act as a carbon sink, removing some $CO_2(g)$ from the atmosphere.

$$CO_2(g) \rightleftharpoons CO_2(aq)$$

Aqueous carbon dioxide, $CO_2(aq)$, quickly reacts with ocean water in a new equilibrium reaction. Construct the equilibrium equation for this reaction including state symbols. [1]

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(Option C continues on the following page)

(Option C, question 14 continued)

(ii) Describe how large amounts of CO_2 could reduce the pH of the ocean using an equation to support your answer. [2]

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(c) Synthesis gas, or syngas, mainly composed of CO(g) and H_2(g), is an alternative form of fuel. It can be produced by coal or biomass gasification, passing steam over the source material in a low oxygen environment.

(i) Suggest an equation for the production of syngas from coal. [1]

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(ii) The Fischer-Tropsch process, an indirect coal liquefaction method, converts CO(g) and H_2(g) to larger molecular weight hydrocarbons and steam.

Deduce the equation for the production of octane by this process. [1]

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(iii) Suggest a reason why syngas may be considered a viable alternative to crude oil. [1]

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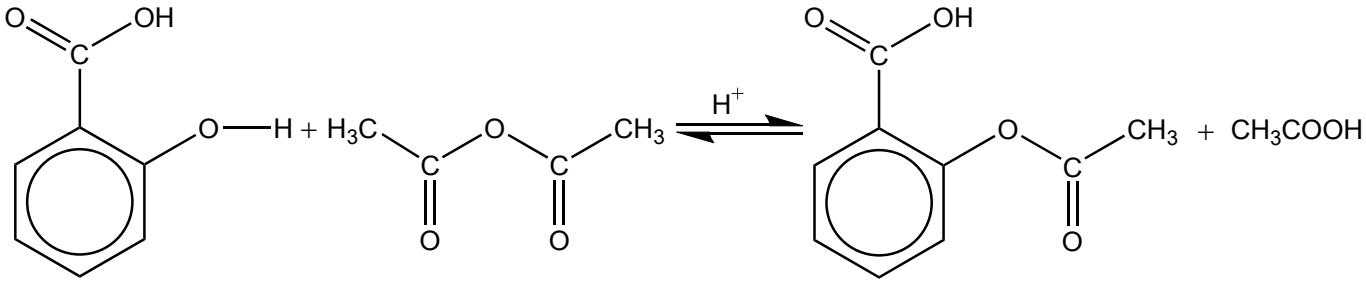
End of Option C

Option D — Medicinal chemistry

15. Aspirin is one of the most widely used drugs in the world.

(a) Aspirin was synthesized from 2.65 g of salicylic acid (2-hydroxybenzoic acid) ($M_r = 138.13$) and 2.51 g of ethanoic anhydride ($M_r = 102.10$).



Salicylic acid Ethanoic anhydride Aspirin Ethanoic acid

(i) Calculate the amounts, in mol, of each reactant. [1]

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(ii) Calculate, in g, the theoretical yield of aspirin. [1]

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(iii) State **two** techniques which could be used to confirm the identity of aspirin. [2]

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(Option D continues on the following page)

(Option D, question 15 continued)

(b) (i) State how aspirin can be converted to water-soluble aspirin. [1]

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(ii) Compare, giving a reason, the bioavailability of soluble aspirin with aspirin. [1]

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16. The structures of morphine, diamorphine and codeine are given in section 37 of the data booklet.

(a) Explain why diamorphine passes more readily than morphine through the blood-brain barrier. [2]

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(b) Suggest a reagent used to prepare diamorphine from morphine. [1]

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(c) Suggest **one** reason why codeine is available without prescription in some countries whilst morphine is administered under strict medical supervision. [1]

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(Option D continues on the following page)

(Option D continued)

17. A number of drugs have been developed to treat excess acidity in the stomach.

(a) Two drugs are ranitidine (Zantac) and omeprazole (Prilosec). Outline how they function to reduce stomach acidity. [2]

Ranitidine:

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Omeprazole:

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(b) 0.500 g of solid anhydrous sodium carbonate, $Na_2CO_3(s)$, is dissolved in 75.0 cm^3 of 0.100 mol dm^{-3} sodium hydrogen carbonate solution, $NaHCO_3(aq)$. Assume the volume does not change when the salt dissolves.

$$HCO_3^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H^+(aq) \qquad pK_a = 10.35.$$

Calculate the pH of the buffer solution. [2]

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(Option D continues on the following page)

(Option D continued)

18. The structures of oseltamivir (Tamiflu) and zanamivir (Relenza) are given in section 37 of the data booklet.

(a) (i) Compare and contrast the structures of oseltamivir and zanamivir, stating the names of functional groups. [2]

One similarity:

. . . . . .

One difference:

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(ii) Deduce the wavenumber of one absorbance seen in the IR spectrum of only one of the compounds, using section 26 of the data booklet. [1]

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(b) Suggest **one** ethical consideration faced by medical researchers when developing medications. [1]

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(Option D continues on the following page)

(Option D continued)

19. The production of many pharmaceutical drugs involves the use of solvents.

(a) Suggest **one** problem associated with chlorinated organic solvents as chemical waste. [1]

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(b) Suggest how the principles of green chemistry can be used to solve the environmental problems caused by organic solvents. [1]

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End of Option D