Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 3

8 May 2024

Zone A afternoon | **Zone B** afternoon | **Zone C** afternoon

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 – 4
Option B — Biochemistry	5 – 8
Option C — Energy	9 – 11
Option D — Medicinal chemistry	12 – 15

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Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

1. This question is about the rate of reaction between bromine and methanoic acid.

$$Br_2\,(aq) + HCOOH\,(aq) \rightarrow 2Br^-\,(aq) + 2H^+\,(aq) + CO_2\,(g)$$

(a) State and explain how the rate of this reaction, measured in **mol dm^{-3} s^{-1}**, could be monitored experimentally. [3]

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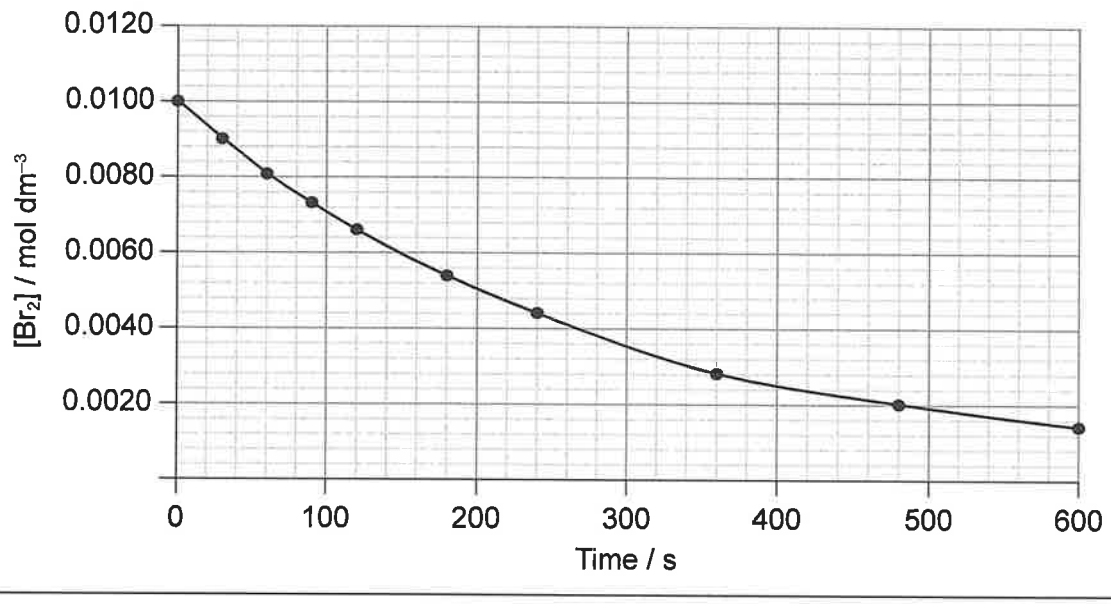
(b) The change in bromine concentration was monitored.



(This question continues on the following page)

(Question 1 continued)

(i) Determine the instantaneous rate of reaction to two significant figures when $[Br_2] = 0.0080\ mol\ dm^{-3}$. [3]

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(ii) Outline why the graph has a negative non-linear slope. [2]

Reason for negative slope:

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Reason for non-linear slope:

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will not be marked.

2. Green chemistry focuses on the design and implementation of chemical processes to reduce waste, conserve energy and discover replacements for hazardous substances.

(a) (i) Four metrics of green chemistry effectiveness are:

Metric	Definition	Result which yields maximum effective green chemistry
Process mass intensity (PMI)	ratio of the masses of all materials used (water, organic solvents, raw materials, reagents, process aids) to the mass of the desired product	1
E-factor	mass of waste divided by mass of desired product	.....
Atom economy	total mass of desired product divided by total mass of all reactants	.....
Eco-Scale	100 minus penalty points (points deducted for low yield, price, safety, technical setup, temperature/time, and purification)	.....

The number that yields the maximum effective green chemistry result is given for PMI.

Estimate a number for each of the other three metrics. [2]

(ii) Identify the metric that does not account for solvent use. [1]

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(iii) Suggest a reason why the pharmaceutical industry has a much worse PMI measure of green chemistry than other chemical industries, such as the oil refining industry or bulk chemical production. [1]

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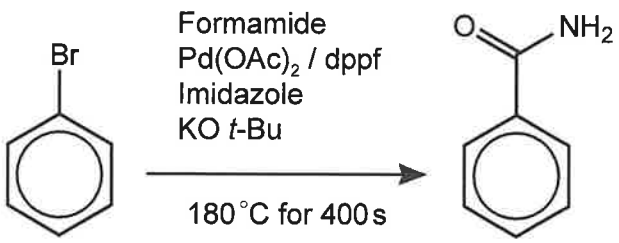
(Question 2 continued)

(b) (i) There are two methods of producing benzamide from bromobenzene. Scheme 1 is shown below.



Scheme 1 has a yield of 82 %, requires a nitrogen atmosphere and is activated via microwave radiation.

The MSDS safety codes for the affected reagents are:
Bromobenzene (N), Formamide (T), KO *t*-Bu (F), dppf (T)

Eco-Scale = 100 – penalty points.

Penalty point deductions based on Eco-Scale:

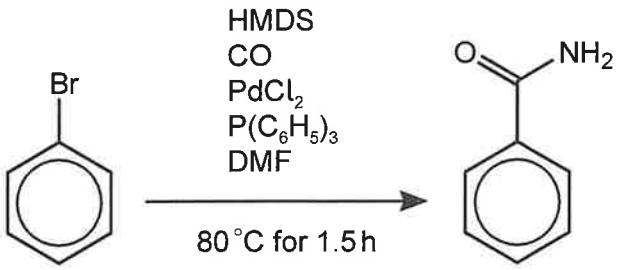
Parameter	**Penalty points**
N (dangerous for environment)	5
T (toxic)	5
F (highly flammable)	5
F+ (extremely flammable)	10
Yield	$\frac{(100 - \%\text{yield})}{2}$
Unconventional/electromagnetic activation technique	2
(Inert) gas atmosphere	1
Heating < 1 hour	2
Heating > 1 hour	3

(This question continues on the following page)

(Question 2 continued)

Determine the Eco-Scale for Scheme 1, ignoring $Pd(OAc)_2$ and imidazole. [2]

(ii) Scheme 2 is shown below.



Scheme 2 has a yield of 76 % and is carried out under a CO atmosphere.

The MSDS safety codes for the affected reagents are:
Bromobenzene (N), CO (T, F+), HMDS (F), DMF (T), $P(C_6H_5)_3$ (N)

Suggest **one** reason why Scheme 2 has a lower Eco-Scale score than Scheme 1. [1]

Section B

Answer **all** of the questions from **one** of the options. Answers must be written within the answer boxes provided.

Option A — Materials

3. Nitinol, NiTi, is a shape memory alloy composed of 50 % nickel atoms and 50 % titanium atoms.

(a) (i) State **two** differences between alloys and composites. [2]

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(ii) Calculate the percentage composition, by mass, of Ni in nitinol. [1]

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(b) Titanium is highly reactive and the production of pure nitinol is difficult. One method of producing high-grade nitinol is by plasma arc melting.

(i) Outline the nature of the plasma state. [1]

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(ii) The plasma torch used is similar to that used in inductively coupled plasma (ICP).

Identify a gas used to produce the plasma. [1]

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(Option A continues on the following page)

(Option A, question 3 continued)

(iii) Explain the significance of this plasma in the production of pure nitinol. [2]

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(c) Chemical vapour deposition (CVD) can be used to produce nitinol or graphene.

Outline the production of graphene nanotubes using CVD. [3]

Source of carbon:

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Conditions:

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(d) Nickel and its compounds can be used as a homogenous or heterogeneous catalyst.

State **one** advantage and **one** disadvantage of a homogenous metal catalyst. [2]

Advantage:

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Disadvantage:

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(Option A continues on the following page)

(Option A continued)

4. Polystyrene is a thermoplastic polymer.

(a) One method of producing the monomer, styrene, is by oxidation of ethylbenzene.

$$C_6H_5CH_2CH_3\,(l) + \frac{1}{2}O_2\,(g) \rightleftharpoons C_6H_5C_2H_3\,(l) + H_2O\,(l)$$

Calculate the percent atom economy for the production of the monomer by this route. Use sections 1 and 6 of the data booklet. [1]

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(b) Distinguish between thermoplastic and thermosetting polymers by referring to the interactions between polymer chains, the effect of reheating them and their ability to be recycled. [3]

Type of polymer	Interactions between chains	Effect of reheating	Can be recycled?
Thermoplastic	. . . . .	. . . . .	. . . . .
	. . . . .	. . . . .	. . . . .
Thermoset	. . . . .	. . . . .	. . . . .
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(c) Some thermoplastics exhibit liquid crystal properties.

Discuss **two** properties, other than chemical stability, these thermoplastics must have in order to be classified as a liquid crystal. [2]

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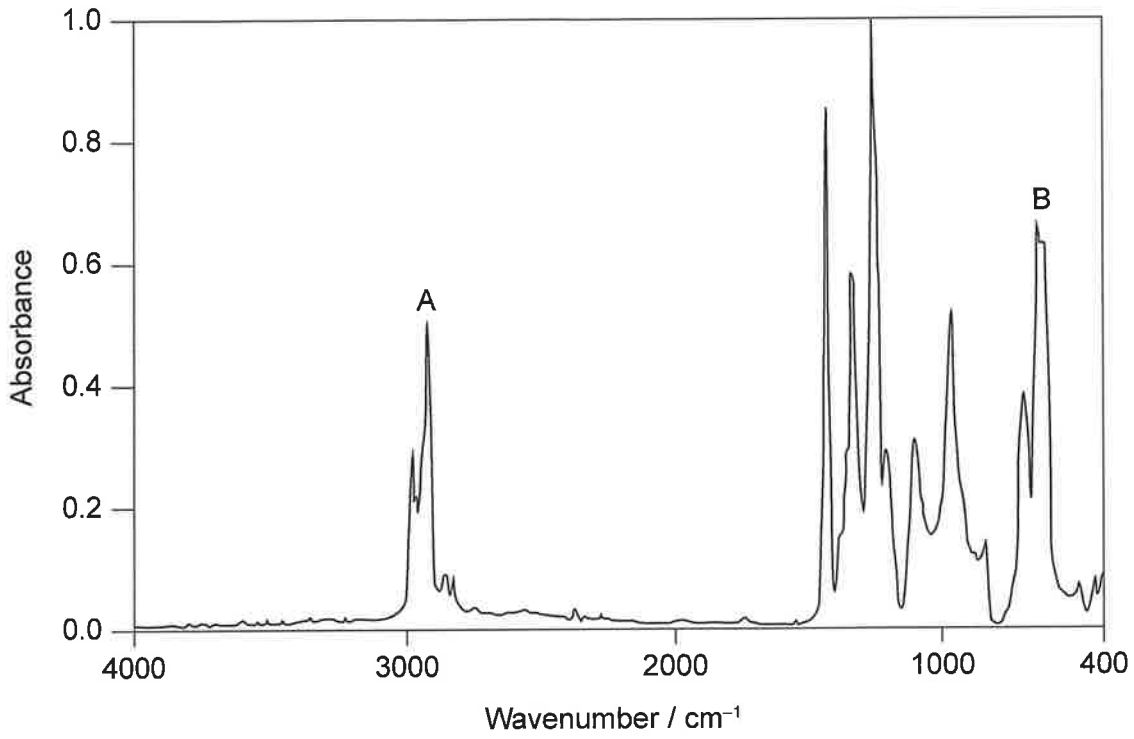
(Option A continues on the following page)

(Option A, question 4 continued)

(d) An IR spectrum of a recyclable plastic is given.



Deduce the bonds in the polymer responsible for the peaks at A and B and the Resin Identification Code (RIC), using sections 26 and 30 of the data booklet. [2]

Bond causing peak A:

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Bond causing peak B:

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RIC:

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End of Option A

Option B — Biochemistry

5. Amino acids combine to form proteins.

(a) (i) Identify the bond responsible for the primary structure of proteins. [1]

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(ii) Identify the type of metabolic process that occurs during synthesis of proteins. [1]

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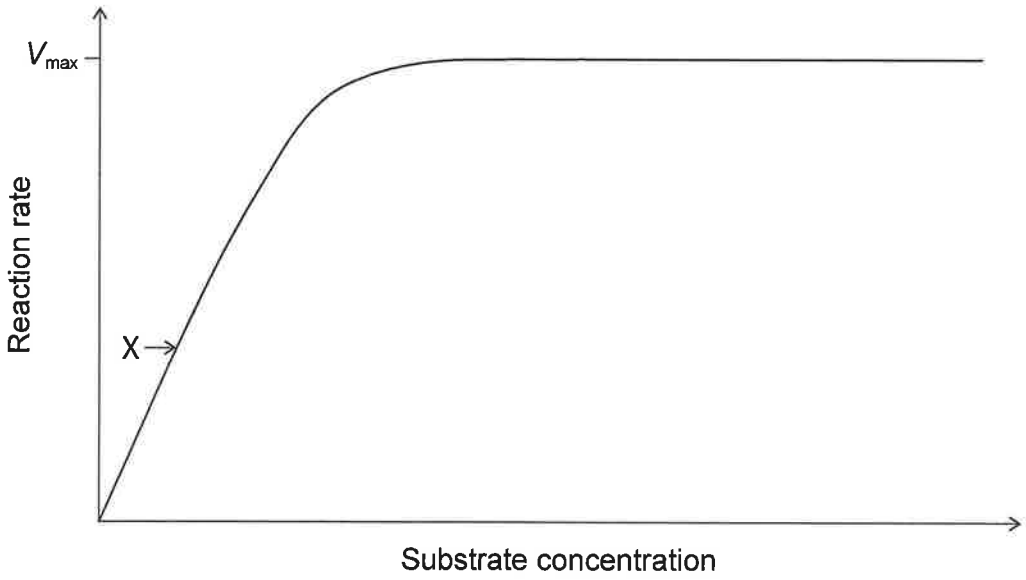
(b) Some proteins act as enzymes, which catalyse biological reactions. Explain the shape of the graph at point X. [2]



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(Option B continues on the following page)

(Option B, question 5 continued)

(c) Explain why globular proteins are able to be transported around the body. [2]

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6. Eicosadienoic acid, $M_r = 308.56$, is a fatty acid found in human milk.

(a) (i) Eicosadienoic acid has an iodine number of 164.5.

Determine the number of C=C double bonds in each molecule of eicosadienoic acid, showing your working. [2]

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(ii) Eicosanoic acid is a saturated fatty acid with the same number of carbon atoms as eicosadienoic acid.

Explain why eicosadienoic acid has a lower melting point than eicosanoic acid. [2]

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(Option B continues on the following page)

(Option B, question 6 continued)

(b) (i) Eicosadienoic acid may undergo rancidity.

Identify **two** conditions that favour the rancidity reaction. [2]

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(ii) State the name of **one** class of organic compound produced by the rancidity reaction. [1]

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(c) Ascorbic acid (vitamin C) may be added to foods to prevent rancidity.

Predict, giving **one** reason, whether ascorbic acid is soluble in oil. Use section 35 of the data booklet. [1]

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7. Monosaccharides and polysaccharides have different properties and functions that are related to their structures.

(a) Describe the structure of a polysaccharide. [2]

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(Option B continues on the following page)

(Option B, question 7 continued)

(b) Glucose or starch can be mixed with active ingredients to produce tablets such as aspirin. The carbohydrate molecules break away to release the drug.

Suggest why a drug made with starch is released more slowly in the stomach than one made with glucose. [1]

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8. Heavy metal toxicity is a problem in the environment.

(a) Suggest **one** source of cadmium pollution. [1]

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(b) Explain how host–guest chemistry can remove cadmium from contaminated waterways. [2]

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End of Option B

Option C — Energy

9. Nuclear fission is an important source of energy.

(a) Outline why only heavy nuclei are capable of spontaneous fission reactions. [1]

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(b) Write the equation for the spontaneous fission of ^{254}Cf into the two smaller nuclei, ^{118}Pd and ^{132}Te. [1]

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(c) Explain the storage and disposal of spent fuel rods from nuclear reactors, which are classified as high-level nuclear waste. [3]

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(d) Fusion reactions can run on abundant cheap fuel and produce minimum radioactive waste. Suggest **one** reason why, despite these advantages, energy is provided from fission rather than fusion reactors. [1]

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(Option C continues on the following page)

(Option C continued)

10. Energy from the sun can interact with molecules in various ways.

(a) Describe global dimming and its causes. [3]

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(b) (i) Identify the feature of chlorophyll that allows it to absorb sunlight. [1]

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(ii) Write the summary equation for photosynthesis. [1]

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(c) Identify the compound that has the largest overall contribution to the greenhouse effect and explain its interaction with infrared radiation. [3]

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(Option C continues on the following page)

(Option C continued)

11. Batteries and fuels provide portable sources of energy.

(a) Suggest, with a reason, if specific energy or energy density is a better measure of a fuel's usefulness as an everyday portable energy source. [1]

(b) (i) Ethylbenzene, $C_6H_5CH_2CH_3$, is an aromatic compound that is used to increase the octane rating in petrol (gasoline). It has a specific energy of $4.135 \times 10^7\,J\,kg^{-1}$.

Calculate the enthalpy of combustion of ethylbenzene, in $kJ\,mol^{-1}$, using section 6 of the data booklet. [2]

(ii) Distillation of crude oil does not yield enough aromatic compounds for addition to petrol. Explain how aromatic compounds are formed from alkanes. [3]

End of Option C

Option D — Medicinal chemistry

12. Antibiotics and antivirals are important in the fight against disease.

(a) Describe how penicillin acts against bacteria. [2]

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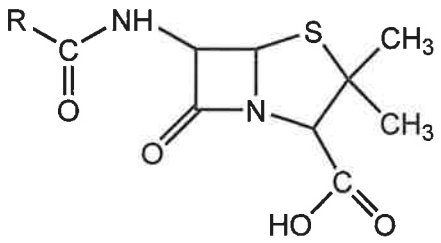
(b) (i) Draw a circle around the section of the penicillin structure that is primarily responsible for its activity. [1]



(ii) Explain, with reference to its structure, why this section of penicillin is reactive. [1]

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(c) Outline the dangers of antibiotic waste in the environment. [1]

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(Option D continues on the following page)

(Option D, question 12 continued)

(d) (i) Oseltamivir (Tamiflu) and zanamivir (Relenza) are antiviral drugs. Their structures are given in section 37 of the data booklet.

Deduce the name of **one** functional group that is in both structures and the name of **one** functional group that is present only in zanamivir. [2]

Functional group in both structures:

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Functional group in zanamivir only:

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(ii) State why viruses are more difficult to target with drugs than bacteria. [1]

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13. Aspirin and codeine are used as pain relievers.

(a) (i) Describe how a strong analgesic, such as codeine, works. [2]

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(ii) Explain why long-term codeine usage is addictive. [2]

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(Option D continues on the following page)

(Option D, question 13 continued)

(b) People can develop tolerance to codeine. Outline the meaning of tolerance. [1]

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(c) State **one** use of aspirin other than for pain relief. [1]

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14. Excess acid in the stomach can cause the breakdown of the stomach lining.

(a) A single dose of an antacid contains 2.320 g of sodium hydrogencarbonate, $NaHCO_3$, and 0.500 g of sodium carbonate, Na_2CO_3.

$M_r(NaHCO_3) = 84.01$ and $M_r(Na_2CO_3) = 105.99$

Determine the amount of stomach acid, in mol, neutralized by this medication. [2]

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(b) Outline how ranitidine (Zantac) inhibits stomach acid production. [2]

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(Option D continues on the following page)

(Option D continued)

15. Many medical procedures involve the use of radioisotopes.

(a) Justify why protective clothing and instruments used in nuclear medicine may be classified as low-level waste. [1]

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(b) Suggest **one** suitable disposal method for this low-level waste. [1]

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End of Option D

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References:

1. (b)(i) Science Skool. *Kinetics.* [pdf] Science Skool. Available at: <http://www.scienceskool.co.uk/uploads/9/5/5/0/9550437/kinetics_a2.pdf> [Accessed 24 April 2019]. REFERENCE REDACTED.

2. (a)(i) Dicks, A.P., Hent, A., 2014. The E Factor and Process Mass Intensity. *Green Chemistry Metrics pp45–67*, [e-journal]. Available through: Springer Link website <https://link.springer.com/chapter/10.1007/978-3-319-10500-0_3?no-access=true> [Accessed 24 April 2019].

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4. (d) FTIR/Raman/NIR Spectral Libraries. [online] NICODOM Ltd. Available at: <http://www.ir-spectra.com/polymers/> [Accessed 29 April 2019]. REFERENCE REDACTED.

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