Markscheme

May 2024

Chemistry

Standard level

Paper 3

Subject details: Chemistry standard level paper 3 markscheme

Candidates are required to answer **ALL** questions in Section A **[15 marks]** and all questions from **ONE** option in Section B **[20 marks]**.
Maximum total = **[35 marks]**.
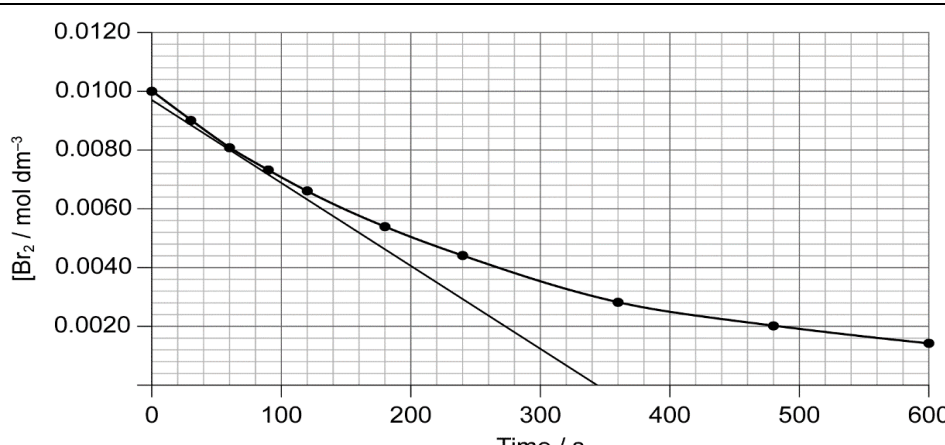
1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "**max**" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative word is indicated in the "Answers" column by a slash (**/**). Either word can be accepted.

6. An alternative answer is indicated in the "Answers" column by "**OR**". Either answer can be accepted.

7. An alternative markscheme is indicated in the "Answers" column under heading **ALTERNATIVE 1** *etc*. Either alternative can be accepted.

8. Words inside chevrons « » in the "Answers" column are not necessary to gain the mark.

9. Words that are <u>underlined</u> are essential for the mark.

10. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

11. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect) in the "Notes" column.

12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.

14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

15. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the "Notes" column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the "Notes" column.

16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.

17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

Section A

Question			Answers	Notes	Total
1.	**a**		**ALTERNATIVE 1**: «monitor/measure» with colorimetry/spectrophotometry/colour change related to $[Br_2]$✓ $[Br_2]$ is proportional to absorbance/transmittance/colour «intensity» ✓ **ALTERNATIVE 2:** «monitor/measure» mass loss/pressure change/volume of gas/CO_2 ✓ moles of CO_2 proportional to mass loss/pressure change/volume ✓ **ALTERNATIVE 3:** «monitor/measure» conductivity/pH ✓ conductivity/pH proportional to ion concentration ✓ **M3 for all ALTERNATIVES:** with respect to time ✓	*Accept other alternatives (e.g., monitor IR absorption of C=O or ^{1}H NMR of the H–C proton) with suitable descriptions.* *Award **[up to 2]** for any two correct methods (M1 in each alternative).* *Accept "weight" for "mass" for Alternative 2.* *M3 must involve some reference to measurement of M1 over time.*	**3**

(Question 1 continued)

	Question		Answers	Notes	Total
1.	**b**	**i**	[Source: With permission from Alex Sullivan (www.scienceskool.co.uk).] tangent drawn on curve at 0.0080 mol dm^{-3} ✓ «Rate = $\dfrac{\Delta[Br_2]}{\Delta t}$ = » 2.8×10^{-5} «mol dm^{-3} s^{-1}» ✓ two significant figures in final answer ✓	*Accept range of* *2.6×10^{-5} to 3.1×10^{-5} «mol dm^{-3} s^{-1}».* *Award **[2 max]** for* *3.3×10^{-5} «mol dm^{-3} s^{-1}».* *Award **[1 max]** for* *3.33×10^{-5} «mol dm^{-3} s^{-1}».* *Ignore negative sign for M2.* *Award M3 for any numerical result with 2 significant figures.*	**3**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**b**	**ii**	*Reason for negative slope:* reactants consumed/used up/fewer reactant molecules «as reaction progresses» **OR** [Br_2] decreasing ✓ *Reason for non-linear slope:* reaction is first order with respect to bromine/Br_2 **OR** lower frequency of collisions «between molecules» **OR** fewer «successful» collisions per unit time «so rate of reaction decreases»	*Accept "reaction is **not** zero order wrt Br_2" for M2.* *Do **not** accept order of reaction without relation to Br_2 stated.* *Do **not** accept "reaction is second order wrt Br_2" for M2.* *Do **not** accept just "rate of reaction decreases" without reference to collisions*	**2**

Question			Answers	Notes	Total
2.	a	i		*Award **[2]** for three correct answers, **[1]** for two correct.* *Accept "100 %" for "1" and "100".* *Accept "0 %" for "0".*	2
2.	a	ii	atom economy ✓	*Accept "E-factor".*	1
2.	a	iii	products need to be purified/many side products/many isomers ***OR*** small mass of active substance per pill/package ***OR*** more solvent used ***OR*** produces more waste ***OR*** «use of» batch chemistry methods/more steps/process aids/raw materials ***OR*** «pharmaceutical industry» much lower yield ✓		1

The table in question 2.a.i:

Measure	Result that yields maximum effective green chemistry
Process mass intensity (PMI)	1
E-factor	0
Atom economy	1
Eco-Scale	100 ✓✓

(Question 2 continued)

	Question		Answers	Notes	Total
2.	**b**	**i**	«100 – [5 (bromobenzene) + 5 (formamide) + 5 (KOBu-*t*) + 5 (dppf) + $\frac{100-82}{2}$ + 2 (microwave) + 1 (N_2 atmosphere) + 2 (heating < 1 hr)] =» 66 ✓✓	*Award [2] for correct final answer.* *Award [1 max] for answers in range of 62 to 65 OR 67 to 71.*	**2**
2.	**b**	**ii**	sum of «MSDS-related» penalty points greater/uses more reagents that are penalized **OR** lower «%» yield **OR** uses CO/F+ atmosphere «which is toxic/extremely flammable» **OR** more flammable reagents used **OR** has a longer heating time ✓	*Apply List Principle.* *Accept "uses $P(C_6H_5)_3$ «which is dangerous for the environment»".*	**1**

Section B

Option A — Materials

	Question		Answers	Notes	Total
3.	**a**	**i**	at least one metal in an alloy **AND** composites may or may not contain metals ✓ alloys are homogenous «or heterogeneous mixtures » **AND** composites are heterogenous/composed of two phases ✓	*Apply List Principle.* *Accept "composites do not contain metals" for M1.*	**2**
3.	**a**	**ii**	« $\dfrac{58.69}{58.69+47.87} \times 100 =$ » 55.08«%» ✓		**1**
3.	**b**	**i**	electrons **AND** positive ions «in gaseous state» ✓	*Accept "gaseous atoms, «many of» which have lost their electrons".* *Do **not** accept "gaseous ions" alone.*	**1**
3.	**b**	**ii**	helium/He **OR** neon/Ne **OR** argon/Ar ✓	*Accept "nitrogen/N_2".*	**1**

(Question 3 continued)

	Question		Answers	Notes	Total
3.	**b**	**iii**	*Any two of:* inert/non-reactive gas ✓ «highly reactive» titanium will not oxidize/react ✓ produces high temperature to melt titanium/nickel ✓ «more» corrosion resistant/less pitting/contamination ✓		**2 max**
3.	**c**		*Source of carbon:* hydrocarbon/carbon-containing gas/compound ✓ *Conditions:* *Any two of:* mixed with inert gas ✓ heat/high temperature/vaporize compound ✓ «transition metal» catalyst ✓ hydrocarbon/carbon compound decomposes to form carbon «nanotubes» ✓ nanotubes form on catalyst surface ✓	*Accept "ethanol" or specific hydrocarbons for M1.* *Accept "N_2", "H_2", "NH_3" or specific inert gases for M2.* *Accept temperature **OR** range within 600–800 °C for M3.* *Accept specific metals such as Ni, Co or Fe for M5.*	**3 max**

(continued…)

(Question 3 continued)

Question			Answers	Notes	Total
3.	**d**		*Advantage:* *Any one of:* highly selective/specific ✓ «requires» milder conditions /lower concentration ✓ not surface area dependent/no need to be finely divided ✓ offer a broader range of reactions ✓ *Disadvantage:* *Any one of:* difficult to be separated/distil/recover **OR** contributes to more environmental waste ✓ poor thermal stability ✓ «often» limited to liquid/aqueous conditions only **OR** not as effective with gases ✓	*Apply List Principle* *Do **not** accept converse of advantage as disadvantage.*	**2 max**

Question			Answers	Notes	Total
4.	**a**		« $\dfrac{12.01 \times 8 + 1.01 \times 8}{12.01 \times 8 + 1.01 \times 10 + 16} \times 100$ =» 85.25 «%» ✓		**1**

(Question 4 continued)

Question			Answers	Notes	Total
4.	b			*Award **[3]** for 6 correct answers.* *Award **[2]** for 4 or 5 correct answers.* *Award **[1]** for 2 or 3 correct answers.* *Do not accept "hydrogen bonding" for M1* *Accept "can maintain shape under heat"* *Award **[1 max]** if correct statements are reversed for Thermoset and Thermoplast.*	3

Type of polymer	Interactions between chains	Effect of reheating	Can be recycled?
Thermoplastic	«weak» intermolecular/IMFs/London/ dispersion/van der Wall/vdW/ dipole–dipole forces «between layers/chains» **OR** no/few cross-links «between layers/chains»	melts/softens «and can reform»	yes
	— *AND* —	— *AND* —	— *AND* —
Thermoset	«strong» covalent bonds «between layers/chains» **OR** extensive cross-links «between layers/chains» ✓	decomposes **OR** burns ✓	no <<most cannot>> / difficult to recycle ✓

(continued…)

(Question 4 continued)

Question			Answers	Notes	Total
4.	**c**		*Any two of*: linear/flat/long chain molecules «with little branching» **AND** can align «along a fixed axis in space» ✓ polar **AND** able to change orientation/rapid switching speed «when subjected to voltage» ✓ stable phase **AND** over suitable temperature range ✓	*Apply List Principle* *Award **[1 max]** for two properties with no explanation.*	**2**
4.	**d**		*Bond causing peak A:* C–H **AND** *Bond causing peak B:* C–Cl ✓ *RIC:* 3 ✓		**2**

Option B — Biochemistry

Question			Answers	Notes	Total
5	**a**	**i**	amide **OR** peptide bond ✓	*Accept "C(O)−NH".* *Do **not** accept "covalent".* *Do **not** accept "C−N".*	**1**
5	**a**	**ii**	anabolism/anabolic «condensation» ✓		**1**
5.	**b**		rate increases as substrate concentration increases ✓ rate proportional to [S] ✓	*Award **[2]** if M2 is explicitly stated.*	**2**
5.	**c**		polar/ionic/charged groups ≪on outside of protein≫ ✓ water-soluble/can form hydrogen bonds/electrostatic attractions ≪with water ≫/ion-dipole ✓		**2**

Question			Answers	Notes	Total
6	a	i	*Alternative 1:* $n(\text{acid}) \ll= \dfrac{100}{308.56} =\gg 0.324 \text{«mol»}$ ***AND*** $n(I_2) \ll= \dfrac{164.5}{2 \times 126.90} =\gg 0.648 \text{«mol»}$ ✓ $\ll \dfrac{0.648\,\text{mol}}{0.324\,\text{mol}} =\gg 2 \text{«C=C bonds»}$ ✓ *Alternative 2:* $\ll\dfrac{164.5\,\text{g} \times 308.56\,\text{g mol}^{-1}}{100\,\text{g}} = \gg 507.7$ ✓ $\ll\dfrac{507.7}{253.8} = \gg 2 \text{«C=C bonds»}$ ✓	*Do **not** award M1 or M2 without correct work.*	**2**

(Question 6 continued)

	Question		Answers	Notes	Total
6	**a**	**ii**	«eicosadienoic acid has» kinks in chain **OR** «eicosadienoic acid» chains pack less closely together ✓ weaker London/dispersion/instantaneous dipole-induced dipole forces «between molecules» ✓	*Accept "eicosadienoic acid has lower surface area/electron density" for M1.* *Do **not** accept "unsaturated" or "contains C=C bonds" for M1 as terms included in stem and previous question.* *Do **not** accept arguments based on size/molar mass/molecular mass of molecule alone.* *Accept "weaker intermolecular/van der Waals'/vdW forces" for M2.*	**2**
6	**b**	**i**	*Any two of:* «sun/UV»light ✓ heat/high temperature ✓ oxygen/O_2 «from air» ✓ enzymes ✓ bacteria ✓ acid ✓ moisture ✓ metal ion catalysts ✓	*Apply List Principle* *Accept answers related to oxidative and hydrolytic rancidity.*	**2 max**

(Question 6 continued)

	Question		Answers	Notes	Total
6	**b**	**ii**	*Any one of:* aldehyde **OR** ketone **OR** alcohol ✓	*Apply List Principle* *Accept "carbonyl".* *Accept "hydroxyl" but **not** "hydroxide".*	**1**
6.	**c**		insoluble **AND** «many» hydroxyl/OH groups **OR** insoluble **AND** polar molecule/groups ✓	*Apply List Principle* *Accept "no/not soluble" for insoluble.* *Accept "'alcohol" for OH groups.* *Do **not** accept "hydroxide" **OR** "react(s) with water"*	**1**

	Question		Answers	Notes	Total
7.	**a**		polymer of glucose/fructose/maltose/monosaccharides ✓ glycosidic bonds «between monomers» ✓	*Accept "made of glucose" for M1.* *Accept "ether" for M2.*	**2**

(Question 7 continued)

Question			Answers	Notes	Total
7.	**b**		glucose is water soluble ***OR*** starch must be digested/hydrolized/is less water soluble ✓	*Accept "broken/break down" instead of "digested/hydrolyzed" for starch.*	**1**

Question			Answers	Notes	Total
8.	**a**		*Any one of:* mining/smelting ✓ «NiCd» batteries ✓ «stabilizers in» plastics ✓ metal plating ✓ pigments/paint ✓ sewage sludge ✓ electronic/e-waste ✓	*Apply List Principle*	**1 max**
8	**b**		«host selectively» bond/binds to cadmium/Cd/Cd^{2+}/metal «ion» ***OR*** complementary chemical structure of host molecule and metal ✓ «supramolecule/host and cadmium» anchored/filtered/precipitated ✓	*Do **not** accept "specifically bind" for M1 as this is rare for synthetic host molecule.* *Do **not** accept "trap" for M1.* *Accept "supramolecule removed" for M2.* *Do **not** accept "removed" by itself for M2.*	**2**

Option C — Energy

	Question		Answers	Notes	Total
9.	**a**		smaller nuclei cannot increase binding energy «by splitting/fission» **OR** require less energy to overcome the nuclear forces of attraction ✓	*Do **not** accept answers only in terms of instability of heavy nuclei.*	**1**
9.	**b**		$^{254}Cf \rightarrow {}^{118}Pd + {}^{132}Te + 4n$ **OR** $^{254}_{98}Cf \rightarrow {}^{118}_{46}Pd + {}^{132}_{52}Te + 4{}^{1}_{0}n$ ✓	*Penalize incorrect atomic numbers.* *Do **not** accept equations induced by neutrons or other particles.*	**1**
9.	**c**		stored in cooling ponds/water **OR** allow for cooling time ✓ encased in cement/glass/steel ✓ buried/disposed «deep» underground/in stable geological locations ✓	*Reference to store/time is needed for scoring M1.* *Do **not** accept "iron" for "steel" for M2.*	**3**

(Question 9 continued)

	Question		Answers	Notes	Total
9.	**d**		«very» high temperature needed «for fusion» *OR* lack of material capable of withstanding high heat «for fusion» *OR* high «electric» cost to heat chamber «for fusion» *OR* technology available for «controlling» fission «but not fusion» ✓	*Do **not** accept generic answers about fusion reaction being dangerous or exploding.*	**1**

	Question		Answers "	Notes	Total
10.	**a**		reduction in «sun's» energy/light reaching Earth's surface ✓ *Any two of:* pollutants/aerosols/particles create «nucleation sites for» cloud «formation» ✓ «some» pollutants/aerosols/particles absorb sunlight/light ✓ «some» clouds/pollutants/aerosols/particles reflect sunlight/light ✓		**3 max**
10	**b**	**i**	highly conjugated systems *OR* many alternating single and double bonds *OR* many delocalized electrons ✓		**1**

(Question 10 continued)

	Question		Answers	Notes	Total
10.	**b**	**ii**	$6CO_2$ (g) + $6H_2O$ (l) $\rightarrow$ $C_6H_{12}O_6$ (aq) + $6O_2$ (g) ✓		**1**
10.	**c**		water/H_2O «vapour» ✓ *Any two of:* «IR radiation is» absorbed by bonds/molecules ✓ bonds stretch/bend/change vibration mode ✓ «producing» change in dipole/polarity ✓	*Accept appropriate diagram.* *Award [2 max] if methane/CH_4/carbon dioxide/CO_2 identified for correct M2 and M3.*	**3**
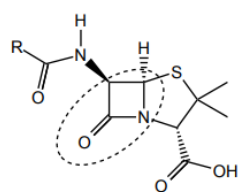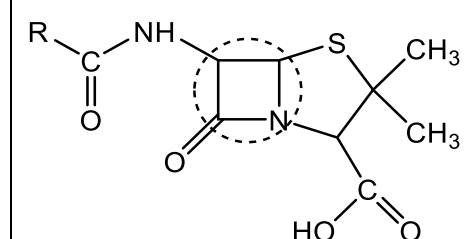
	Question		Answers	Notes	Total
11.	**a**		energy density **AND** requires less storage space **OR** gases need «extra weight for» compression equipment **OR** «small volume» easier to transport/carry **OR** high specific energy with low energy density technologies are cost prohibitive ✓		**1**

(continued…)

(Question 11 continued)

	Question		Answers	Notes	Total
11.	**b**	**i**	M_r ethylbenzene = 106.18 g mol^{-1} ✓ «$\Delta H_c = \dfrac{-4.135 \times 10^7 \text{ J kg}^{-1}}{1000 \text{ g kg}^{-1}} \times \dfrac{106.18 \text{ g mol}^{-1}}{1000 \text{ J kJ}^{-1}} =$» -4391 «kJ mol^{-1}» ✓	*Award [2] for correct final answer.* *Award [1 max] for missing negative sign in answer.* *Award [2] for -4380 «kJ mol^{-1}» for M2 when 106 g mol^{-1} used for M1.*	**2**
11	**b**	**ii**	passed over/use «metal/platinum» catalyst «with aluminium oxide» ✓ dehydrogenates/loses hydrogen/is oxidized ✓ reforms/cyclizes ✓	*Award M1 and M3 for "catalytic reforming".* *Correct structures/equations can be accepted for any mark.*	**3**

Option D — Medicinal chemistry

	Question		Answers	Notes	Total
12.	**a**		«irreversibly» binds/bond to enzyme /transpepidadase ***OR*** inhibits enzyme/transpeptidadase «in bacteria» that produces cell walls ***OR*** prevents cross-linking of bacterial cell walls ✓ cells absorb water ***AND*** burst ***OR*** cell cannot reproduce ✓	*Award **[1 max]** for "interferes with cell wall production.* *Accept "reacts with" for "bonds to" for M1.* *Do **not** accept "cell membrane" for "cell wall" for M1.* *Accept "cells burst due to osmotic pressure" for M2.* *Accept "bacteria" for "cells" for M2.*	**2**
12.	**b**	**i**	 3 C atoms and N atom must be included in circle ✓	*Accept* 	**1**

(continued…)

(Question 12 continued)

	Question		Answers	Notes	Total
12.	**b**	**ii**	*Any one of:* ring is «sterically» strained/breaks up/opened **OR** amide/amido group «in rings» is «highly» reactive **OR** bond angles 90° instead of 109.5°/109°/120° **OR** angles less than 109.5°/109°/120°/tetrahedral/trigonal planar/triangular planar ✓	*Mark can be scored in part (a) of this question.*	**1 max**
12.	**c**		development of bacteria/microorganisms resistant to antibiotics **OR** loss of beneficial bacteria **OR** changes to/mutations of populations of bacteria/microorganisms **OR** leads to penicillinase-producing bacteria **OR** damage to/contamination of bodies of water/ecosystem. **OR** destroyed bacteria replaced by more harmful bacteria ✓	*Accept superbugs" for "bacteria/microorganisms resistant to antibiotics"* *Do **not** accept "antibiotic resistance" alone or if applied incorrectly.* *Accept "endocrine disruptor".* *Do **not** accept "increased cost of developing antibiotics".*	**1**

(Question 12 continued)

	Question		Answers	Notes	Total
12.	**d**	**i**	*Functional group in both structures:* *Any one of:* amido ✓ ether ✓ carbonyl ✓ *Functional group in zanamivir only:* *Any one of:* hydroxyl ✓ carboxyl ✓	*Apply List Principle* *Accept "amide/carboxamide" for M1.* *Accept "alkenyl/alkene" for M1.* *Accept "amino/amine" for M1.* *Accept "hydroxyl/alcohol" but **not** "hydroxide" for "hydroxyl" for M2.* *Accept "imine" **OR** "guanidino" for M2.*	**2 max**
12.	**d**	**ii**	lack cell structure/cell wall/«surrounded by protective» protein coating ***OR*** cannot perform any biological functions on their own/rely on host cell ***OR*** mutate quickly «so antivirals quickly become obsolete» ***OR*** «significantly» smaller ✓		**1**

	Question		Answers	Notes	Total
13.	**a**	**i**	«temporarily» binds to/blocks opioid/pain receptors in brain/CNS ✓ prevents transmission of pain impulses in the brain/CNS «without depressing the CNS» ✓	*Reference must be made to the brain/CNS once only for both marks.*	**2**
13.	**a**	**ii**	*Any two of:* releases dopamine/endorphins «that the person craves» ***OR*** gives a feeling of pleasure/euphoria «that the person craves» ✓ alters the structure of brain cells ***OR*** alters the way brain works «so that it only works normally when the opiates are present» ✓ «once addicted» withdrawal symptoms occur without continual use ✓		**2 max**
13.	**b**		body's response to drug is reduced «when drug is used repeatedly» ***OR*** more of the drug needs to be taken to achieve the original/same effect ✓	*Accept "body adapts/gets used to the continuous presence of drug".*	**1**

(Question 13 continued)

	Question		Answers	Notes	Total
13.	**c**		anticoagulant/reduces blood clotting/blood thinner ***OR*** prevents cardiovascular disease/stroke/CVA ***OR*** reduces fever/antipyretic ***OR*** anti- inflammatory ✓	*Apply List Principle* *Accept "prevents/reduces risk of heart attack"* ***OR*** *"prevent heart disease"* ***OR*** *"may reduce colon/colorectal cancer".*	**1**

	Question		Answers	Notes	Total
14.	**a**		«$n(NaHCO_3) = \dfrac{2.320}{84.01}$ and $n(Na_2CO_3) = \dfrac{0.500}{105.99}$ » $n(NaHCO_3) = 0.0276$ «mol» ***AND*** $n(Na_2CO_3) = 0.0047$ «mol» ✓ $n(HCl)$ «$= 0.0276 + 2 \times 0.0047$» $= 0.0370$ «mol» ✓	*Award **[2]** for correct final answer.* *Accept 0.0371 «mol» for **[2]**.*	**2**
14.	**b**		blocks/binds to H2/histamine receptors «in cells of stomach lining» ***OR*** prevents histamine molecules binding to H2/histamine receptors «and triggering acid secretion» ✓ prevents «parietal» cells/stomach lining from releasing/producing acid ✓	*Accept "H2-receptor antagonist/H2RA"* ***OR*** *"blocks/inhibits action of histamine" for M1.* *Do **not** accept just "inhibits acid production" for M2.*	**2**

Question			Answers	Notes	Total
15	**a**		low activity/radioactivity **AND** has short half-life ✓	*Accept "emits weak ionizing radiation" for "low activity/radioactivity".* *Accept "exists for a short period of time" for "short half-life".*	**1**
15	**b**		store in sealed/shielded container **AND** until material has decayed/becomes inactive **AND** then dispose «with normal waste»/in landfill/incineration ✓	*Apply List Principle*	**1**