Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2023

Chemistry

Higher level

Paper 3

31 pages

Subject details: Chemistry higher 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 **[30marks]**.
Maximum total = **[45marks]**.

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)		gases «and others are solids» ✓	*Do **not** accept "lower density" alone.*	1
1.	(b)		smaller values are diatomic «gases» ***OR*** larger values are monatomic «gases» ✓	*Accept "smaller values are species that exist as molecules".* *Do **not** accept answers referring only to noble gases or electron configurations.*	1
1.	(c)		«different» allotropes ✓	*Accept "different structural forms" **OR** "oxygen forms different molecules".* *Accept correct formulas or names of allotropes.* *Accept monatomic oxygen/O only if mentioned with respect to other allotropic form or explanation provided.* *Do **not** accept "different isotopes" alone.*	1
1.	(d)		*Any two of:* increasing «effective» nuclear charge/Z/atomic number/number of protons ✓ increasing number of delocalized/bonding/valence electrons ✓ increasing attractions between positive «metal» ions/cations and delocalized electrons ***OR*** stronger metallic bonding ***OR*** decreasing radii ✓		2 max

Question			Answers	Notes	Total
1.	(e)		any estimated value in the range of 20-40 «$cm^3\ mol^{-1}$». ✓	*Accept any range of values also between 20 to 40 «$cm^3\ mol^{-1}$».*	1
1.	(f)		no ***AND*** probability of finding an electron is low ***OR*** no ***AND*** all measurements have uncertainties «even though there will always be uncertainty as to what the exact value is» ***OR*** yes ***AND*** X-ray diffraction can indicate separation of nuclei «in the element» ***OR*** yes ***AND*** can take a sample of the element, measure its volume and calculate number of particles ***OR*** yes ***AND*** bond length can be measured by microwave spectroscopy/electron diffraction/neutron diffraction ✓	*Accept "no **AND** position of electron cannot be determined" for M1.* *Accept "no **AND** atoms made up of « mainly» empty space that cannot be measured" for M1.* *Accept "no **AND** atoms have different volumes in different states «of matter»" for M1.* *Accept "no **AND** the distance between two nuclei is measured and the radius/volume/size of atom is estimated" for M1.* *Accept references to the Heisenberg uncertainty principle for M1.*	1

2.	(a)	(i)	green to purple ***OR*** green to brown ***OR*** green to purple-green ✓	*Accept "colourless to purple".* *Accept "green to grey/blueish".* *Do **not** accept "clear" for "colourless".* *Do **not** accept "purple to "brown".* *Do **not** accept blue as final colour.*	1
2.	(a)	(ii)	none / no effect ✓		1

Question			Answers	Notes	Total
2.	**(b)**		systematic ✓	*Class must be stated, **not** specific examples.*	**1**
2.	**(c)**	**(i)**	$\langle\langle\frac{0.1}{3.1} \times 100 = \rangle\rangle 3 \langle\langle\% \rangle\rangle$ ✓		**1**
2.	**(c)**	**(ii)**	using more dilute potassium manganate(VII) ***OR*** using more dilute titrant ***OR*** larger aliquot/volume of filtrate ✓	*Accept "using a pipette with more precision"* ***OR*** *"using a volumetric flask"* ***OR*** *"using a better balance/scale"* ***OR*** *"determining a more accurate mass".* *Do **not** accept "weight" for "mass".*	**1**

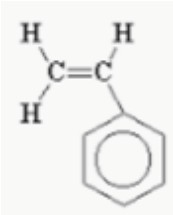
Question			Answers	Notes	Total
2.	(c)	(iii)	***ALTERNATIVE 1*** mass Fe in the 79.6 g kale ⟨⟨$= 8.66\text{x}10^{-4} \times \frac{500}{10.0}$⟩⟩ = 0.0433 «g» ✓ percent by mass ⟨⟨$= \frac{0.0433}{79.6} \times 100$ ⟩⟩ = 0.0544«%» ✓ ***ALTERNATIVE 2*** mass of kale in titration flask ⟨⟨$= 79.6 \times \frac{10.0}{500}$⟩⟩ = 1.592 «g» ✓ percent by mass ⟨⟨$= \frac{8.66\text{x}10^{-4}}{1.592} \times 100$ ⟩⟩ = 0.0544«%» ✓	*Award **[2]** for correct final answer.* *For **ALTERNATIVE 2:*** *Award M1 for either 1.59 «g» **OR** 1.592 «g» **and*** *Award M2 for 0.0545«%» **OR** 0.0544«%».* *M2 must be to 3 sig. fig.* *Award **[1 max]** for 0.00109«%».*	**2**
2.	(d)		other substances in the leaves «as well as iron» react with the manganate(VII) «ion» ***OR*** kale modified to have more iron/Fe ***OR*** iron/Fe in water/pipes/container used for boiling ***OR*** manganate(VII) oxidized/reacted with other ions/substances/metals ***OR*** manganate(VII) concentration changes over time ✓	*Accept "different species of kale can result in more iron/Fe «content»"* ***OR*** *"sample of kale not representative"* ***OR*** *"sample of kale grown in different soils"* ***OR*** *"kale sample being dry/dehydrated".*	**1**

Section B

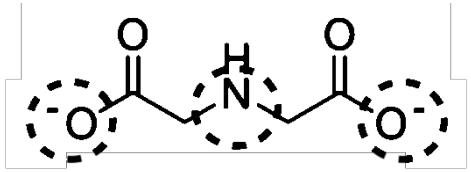
Option A — Materials

Question			Answers	Notes	Total
3.	**(a)**		*Any one of:* Zn, Cr, Fe, Cd, Co, Ni, Sn, Pb, Sb, As, Bi, Cu, Ag, Pd, Hg, Pt ✓	*Accept "Au".* *Accept name or symbol of metal.*	**1**
3.	**(b)**	**(i)**	$Al^{3+} + 3\ e^- \rightarrow Al(l)$ ✓	*Do **not** penalize if equilibrium arrow used.*	**1**
3.	**(b)**	**(ii)**	$\langle\langle \frac{2 \times 26.98}{2 \times 26.98 + 3 \times 16.00} x100 = \rangle\rangle$ 52.92% ✓	*Accept "0.5229".*	**1**
3.	**(b)**	**(iii)**	high energy consumption «that has environmental implications» ***OR*** large amounts of waste «produced by mining and purification of the ore» ***OR*** mining has negative impact on landscape ***OR*** greenhouse gas/pollution from transport/machinery ✓	*Accept "fluorine/fluorine compounds produced" or their formulas.* ***OR*** *"carbon dioxide/carbon monoxide released".*	**1**
3.	**(b)**	**(iv)**	average electronegativity 2.5 ***AND*** electronegativity difference 1.8 ✓ border between ionic and «polar» covalent ✓	*Accept "partially covalent/high covalent character" for M2.* *Award **[2]** for calculation of %ionic character = «1.8/3.2 =» 56%.*	**2**

Question			Answers	Notes	Total
3.	**(c)**	**(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.	**(c)**	**(ii)**	*Identification:* «emit» light/photons of characteristic frequencies ✓ *Concentration*: intensity/brightness of light «proportional to concentration» ✓	*For M1 accept "energies/wavelengths" for "frequencies".* *For M2 accept "signal strength/peak height".* *Do **not** accept a general statement such as "concentrations can be detected by absorbance of the radiation «in OES»" for M2.*	**2**
3.	**(d)**		«held together by strong» covalent bonds «and defect free/regular 2D/3D» ✓		**1**

4.	**(a)**	**(i)**	 ✓	*Accept "-C_6H_5" for phenyl group.*	**1**
4.	**(a)**	**(ii)**	B ***AND*** chains «of polymer» can align/pack more closely ✓	*Do **not** accept "stronger intermolecular forces between chains".*	**1**

Question			Answers	Notes	Total
4.	**(b)**		forms an intermediate/activated complex ✓ «intermediate/activated complex» dissociates to form product «***AND*** catalyst» ✓	*Accept correct annotated energy profile for either mark.*	**2**
4.	**(c)**		«lyotropic liquid crystals» exist over a given concentration range ***AND*** other liquid crystals exist over a certain temperature range ✓		**1**
4.	**(d)**	**(i)**	volatile hydrocarbon/pentane «incorporated in beads of the polymer» ✓ vaporizes/boils when heated «causing polymer to expand» ✓	*Accept names or formulas for M1.* *Accept "carbon dioxide" for M1.*	**2**
4.	**(d)**	**(ii)**	«good» thermal/electrical insulator ***OR*** soft/provides shock resistance ***OR*** low density ***OR*** easily moulded/versatile ***OR*** water resistant ***OR*** durable ✓	*Accept "easy on-site usage"* ***OR*** *"environmentally sustainable"* ***OR*** *"non-toxic"* ***OR*** *«chemically» inert".* *Accept "lightweight" for "low density".*	**1**
4.	**(e)**		*Type of polymerization:* condensation ✓ *Structural characteristic:* two functional groups ✓	*Accept "polycondensation" for M1.*	**2**
4.	**(f)**		strong covalent bonds ✓	*Accept "close packing of chains"* ***OR*** *"hydrophobicity".*	**1**
4.	**(g)**		«RIC» 7 ✓		**1**

Question			Answers	*Notes*	Total
5.	**(a)**	**(i)**	6 ✓		**1**
5.	**(a)**	**(ii)**	6 on faces «shared between two unit cells» so 6x½ = 3 ✓ 8 on corners «shared between eight unit cells» so 8x⅛ = 1 ✓		**2**
5.	**(a)**	**(iii)**	X-ray crystallography/diffraction ✓	*Accept "electron/neutron diffraction".*	**1**
5.	**(b)**		$H^+] = 10^{-9}$ «mol dm^{-3}» ✓ $[OH^-]$ ⟨⟨$= \frac{10^{-14}}{10^{-9}}$⟩⟩ = 10^{-5} «mol dm^{-3}» ✓ $[Pb^{2+}]$ ⟨⟨$= \frac{1.43x10^{-20}}{(10^{-5})^2}$⟩⟩ = $1.43x10^{-10}$«mol dm^{-3}» ✓	*Award **[3]** for correct final answer.* *Accept alternative ways of carrying out the calculation.*	**3**
5.	**(c)**		 ✓	*Accept circles around the carbonyl oxygens instead of those with the negative charges **OR** circles enclosing both carbonyl oxygens.* *Do **not** award the mark if more than 3 circles are drawn.*	**1**

Option B — Biochemistry

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>6.</td><td></td><td></td><td>$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ ✓</td><td></td><td>1</td></tr>
<tr><td>7.</td><td>(a)</td><td></td><td>
<table>
<tr><th>Structure Level</th><th>Interactions between amino acids</th></tr>
<tr><td>primary</td><td>covalent bonding
OR
peptide bond
OR
amide bond ✓</td></tr>
<tr><td>secondary</td><td>hydrogen bonding ✓</td></tr>
<tr><td>tertiary</td><td>interactions between R groups/side chains
OR
ionic/electrostatic «attraction»
OR
hydrogen bonding
OR
hydrophobic interactions
OR
disulfide bridges
OR
London/dispersion/van der Waals/«instantaneous» induced dipole-induced dipole ✓</td></tr>
</table>
</td><td>Do not accept “amino acid sequence” for M1.

Do not accept “alpha helix” OR “beta sheets” for M2.

Accept “covalent bonding” for M3.</td><td>3</td></tr>
</table>

Question			Answers	Notes	Total
7.	(b)		*Any two of:* sample spotted on paper/stationary phase ***AND*** solvent moves up the paper ***OR*** continuous cycles of adsorption and desorption/dissolution ***OR*** analyte moves when in solvent ***AND*** does not move when on paper ✓ different/depends on attractions to mobile phase ***AND*** stationary phase/paper ***OR*** «amino acids» separated based on solubilities in/affinity to the two phases ***OR*** separated based on polarities/polar attractions/molar masses of «amino acids» ✓ developed with ninhydrin/reagent/locating agent ***OR*** become identified with UV «light» ✓ «amino acids» identified by R_f/retention factor «values» ***OR*** R_f/retention factors «values» compared with known samples ✓		**2 max**
7.	(c)		product of reaction is inhibitor of enzyme ***OR*** product binds/bonds to allosteric site of enzyme ✓ regulates own production ***OR*** sets up feedback loop to control concentration/production ✓		**2**

Question			Answers	Notes	Total
7.	**(d)**		0.520 «mg cm^{-3}»✓	*Accept any value in range 0.510-0.530* «mg cm^{-3}».	**1**

8.	**(a)**		*Compare rancidity:* «both produce» disagreeable smell/taste/texture/appearance ✓ *Contrast reaction site:* hydrolytic reaction occurs at ester link/COOC link ***AND*** oxidative reaction occurs at carbon-carbon double bond/C=C ✓	*Do **not** accept "double bond" alone for oxidative reaction site.*	**2**
8.	**(b)**		5 C=C ✓ «100 g/330.56 g mol^{-1} x 5 x 253.8 g mol^{-1} =» 383.89 «g I_2» ✓	*Award **[2]** for correct final answer.*	**2**
8.	**(c)**		lipids are more reduced ***AND*** release/store more energy than carbohydrates «per gram» ✓ lipids are less «water» soluble ***AND*** energy is released slower/less available than in carbohydrates ✓	*Accept converse arguments.* *Award **[1 max]** for "carbohydrates used for short-term energy supply **AND** lipids used for long-term energy supply"* ***OR*** *"lipids more reduced **AND** less «water» soluble".*	**2**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>9.</td><td></td><td></td><td>Bond:
glycosidic✓

By-product:
water/H_2O ✓</td><td>Accept “ether/C-O-C”
OR
“covalent/polar covalent” for M1.</td><td>2</td></tr>
<tr><td>10.</td><td></td><td></td><td>«mostly» not synthesized by body «and needed for proper growth/metabolism» ✓</td><td>Do not accept “needed for proper growth/metabolism” alone.</td><td>1</td></tr>
<tr><td>11.</td><td></td><td></td><td>Any two of:

host molecule/supramolecule forms complex/bond with guest/xenobiotic ✓

binding between host and guest specific ✓

bonding «usually» non-covalent «in both cases» ✓</td><td>Accept “supermolecule” for “supramolecule”.</td><td>2 max</td></tr>
<tr><td>12.</td><td></td><td></td><td>
<table>
<tr><th>DNA:</th><th></th><th>RNA:</th></tr>
<tr><td>thymine</td><td>AND</td><td>uracil ✓</td></tr>
<tr><td>deoxyribose</td><td>AND</td><td>ribose ✓</td></tr>
<tr><td>double stranded</td><td>AND</td><td>single stranded ✓</td></tr>
</table>
</td><td>Accept “additional methyl/CH_3 group” for DNA OR “one less methyl group” for RNA for M1.

Accept “one less hydroxyl/OH group” for DNA OR “additional hydroxyl/OH group” for RNA for M2.</td><td>3</td></tr>
</table>

Question			Answers	Notes	Total
13.	(a)		contains many/multiple conjugated «carbon–carbon/C=C» double bonds ***OR*** extended system of delocalized electrons ✓ absorbs blue ***OR*** complementary to orange «light» ✓	*M1 requires the concept of many or multiple conjugated double bonds in structure for mark.* *Do **not** accept either "conjugation" **OR** "double bonds" alone for M1.*	**2**
13.	(b)		*Any two of:* equilibrium shifts right ***OR*** H^+ ions lost ✓ red to blue ✓ loss of proton/H^+ changes extent of conjugation✓ affects frequency/wavelength of absorbed light ✓ complementary light transmitted ✓	*Do **not** accept "cation red and base blue" alone.* *Apply ECF from M1 to M2.*	**2 max**

Question			Answers	Do Notes	Total
14.	**(a)**		*Similarity:* polymers of glucose ***OR*** «1-4» glycosidic «links» ✓ *Difference:* starch contains α-glucose ***AND*** cellulose contains β-glucose ***OR*** starch contains α ***AND*** cellulose contains β «1-4» glycosidic links ***OR*** starch «may contain» 1-6 glycosidic links ***AND*** cellulose does not ***OR*** starch «may be» branched ***AND*** cellulose unbranched ✓	*Do **not** accept "both are polysaccharides" for M1.* *Accept alpha or beta for symbols in M2.*	**2**
14.	**(b)**		lack of cellulase/enzyme ✓		**1**

Option C — Energy

Question			Answers	Notes	Total
15.	**(a)**	**(i)**	$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$ ✓		**1**
15.	**(a)**	**(ii)**	conjugated «electronic» structure/delocalized «pi» electrons/alternate «single and» double bonds ✓	*Accept "many/delocalized double bonds".* *Do **not** accept "tetrapyrrole group" alone without reference to idea of conjugation.*	**1**
15.	**(a)**	**(iii)**	reduces/sequesters CO_2/carbon dioxide «concentration from atmosphere» ✓ «planting» more plants/trees ✓	*Do **not** accept "carbon capture" alone for M1.* *Do **not** accept just "plants/trees" alone for M2.*	**2**
15.	**(b)**	**(i)**	*Photosynthesis*: chemical ***AND*** *Photovoltaic*: electrical ✓	*Accept "electricity" for "electrical".*	**1**

Question			Answers	Notes	Total
15.	**(b)**	**(ii)**	*Any three of:* n-type ***AND*** p-type «silicon layers» ***OR*** n-type doped with Gp 15 element/P ***AND*** p-type doped with Gp 13 element/B ✓ potential difference/charge separation created between layers of silicon ✓ «sunlight produces» free electrons that flow between layers «from p-type to n-type» ***OR*** «sunlight produces» positive holes that flow between layers «from n-type to p-type» ✓ «excess» electrons move "from n-type to p-type" through an external circuit ✓	*Do **not** accept movement of electrons or holes in wrong direction for M3.*	**3 max**
15.	**(c)**	**(i)**	«(2x-1367 / -2803) x 100 =» 97.54% ***OR*** 2.46% loss «in energy efficiency» ✓		**1**
15.	**(c)**	**(ii)**	liquid ***OR*** easier ignition ***OR*** more volatile ✓	*Accept "complete combustion more likely""* ***OR*** *"better octane rating"* ***OR*** *"engine must be converted in order to use glucose".* *Do **not** accept "less viscous".*	**1**

Question			Answers	Notes	Total
15.	**(d)**	**(i)**	material provides energy in fuel cells ***OR*** fuel continually added in fuel cells ✓	*Accept converse statement.* *Do **not** accept "fuel cells are rechargeable and primary are not easily recharged".*	**1**
15.	**(d)**	**(ii)**	reduce «internal» resistance ✓	*Accept "increase surface area" **OR** "reduce separation of electrodes" **OR** "increase concentration of electrolyte/ion mobility/temperature".*	**1**
16.	**(a)**	**(i)**	reflects «sun» light ✓	*Accept "results in global dimming"* ***OR*** *"reduces the amount of energy reaching the Earth"* ***OR*** *"acts as nucleation points for cloud formation".* *Do **not** accept answers that only indicate increases in global temperatures.*	**1**
16.	**(a)**	**(ii)**	electrical/electricity ✓	*Accept "heat/thermal".*	**1**

Question			Answers	Notes	Total
16.	**(b)**		*Fractional distillation (Any one of):* separates compounds according to boiling points/vapor pressure ***OR*** physical process ***OR*** involves breaking intermolecular forces ***OR*** separates based on molar masses ***OR*** does not use catalyst ✓ *Cracking (Any one of):* shorter hydrocarbon chains formed/lower molar masses ***OR*** increased branching formed ***OR*** increased aromatic ring formation ***OR*** produces alkenes/unsaturated hydrocarbons ***OR*** chemical process ***OR*** new compounds formed/breaking «and remaking»/changing covalent bonds ***OR*** uses catalyst ✓	*M1 is for Fractional distillation.* *M2 is for Cracking.*	**2**

Question			Answers	Notes	Total
16.	(c)	(i)	***ALTERNATIVE 1*** 5470 «kJ» produced when 8 «mol» produced ✓ «8 x 44.01 =» 352 «g» to produce 5470 «kJ» ✓ 1 «kJ» would release «352/5470 =» 0.0644 «g» ✓ ***ALTERNATIVE 2*** 1 «kJ»/5470«kJ=» 1.828×10^{-4} ✓ 8/5470 «mol =» 0.001463 mol ✓ «8/5470 «mol» x 44.01 «$gmol^{-1}$ =» 0.0644 «g» ✓	*Award **[3]** for correct final answer.* *Accept "0.0643 «g»".*	**3**
16.	(c)	(ii)	many fluctuations of temperature have occurred in the «geological» past ***OR*** different global models produce different outcomes ***OR*** industrial emissions are less than natural ones ✓	*Do **not** accept statements about current temperatures.*	**1**

Question			Answers	Notes	Total
17.	**(a)**		*Similarity:* increase binding energy «per nucleon» ***OR*** «can» produce chain reactions ✓ *Difference:* fusion forms one product/products with a greater «atomic» mass ***AND*** fission multiple products/products with a lower mass ***OR*** fission produces «long lived» radioactive products/nuclear waste ***AND*** fusion does not ✓	*Similarity:* *Accept "converts mass to energy".* *Accept "produces ionizing radiation".* *Accept "produces heat".* *Accept "produces mass defect".* *Difference:* *Accept "fission requires critical mass **AND** fusion does not".* *Accept "fuel for fission is radioactive **AND** fuel for fusion is not".* *Accept "fuel for fission are heavy elements/U/Th/Pu **AND** fuel for fusion are light elements/H/He/Li".*	**2**
17.	**(b)**	**(i)**	uranium hexafluoride/UF_6 ✓		**1**
17.	**(b)**	**(ii)**	«^{238}U rate = ^{235}U rate x $(349/352)^{½}$ = ^{235}U rate x » 0.996 ***OR*** «^{235}U rate = ^{238}U rate x $(352/349)^{½}$ = ^{238}U rate x » 1.004 ✓ percentage difference «= (1-0.996) x 100» = 0.4% ✓	*Award **[2]** for correct final answer.* *Do **not** accept "100.4%" as answer for M2.*	**2**

Question			Answers	Notes	Total
17.	**(b)**	**(iii)**	rate of diffusion proportional to v ✓ v inversely proportional to √m ***OR*** $v = (2E/m)^{½}$ ***OR*** $\frac{v_1}{v_2} = \frac{(2E/m_1)^{½}}{(2E/m_2)^{½}}$ ✓	*Accept "both particles have same «kinetic» energy" **OR** "$E_1 = E_2$" for either M1 or M2.*	**2**
17.	**(c)**	**(i)**	*X:* «1»n/neutron ✓ *Y:* ^{239}Pu/Pu-239/plutonium-239 ✓	*Do **not** accept "N" for "neutron" for M1.* *Do **not** accept "plutonium/Pu" alone for M2.*	**2**
17.	**(c)**	**(ii)**	time for half the number of atoms/nuclei/mass to decay ✓	*Accept "time for the radioactivity «produced by that decay» to fall by half".* *Do **not** accept "molecules" for "atoms/nuclei".*	**1**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
18.			*Oral:* low/lower «bioavailability» ***AND*** drugs pass through digestive system «and breakdown» ✓	*Accept "low/lower **AND** drugs not easily absorbed from digestive system"* ***OR*** *"low/lower **AND** drugs broken down in digestive system"* ***OR*** *"low/lower **AND** drugs affected by acid" for M1.* *Do **not** penalize use of "slow" for "low/lower" or "fast" for "high/higher".*	**2**
			Intravenous: high/higher «bioavailability» ***AND*** «more» direct route to bloodstream ✓	*Accept "100% bioavailability" for "high/higher" within Intravenous answer in M2.* *Award **[1 max]** for "oral drugs have slower absorption/distribution than intravenous drugs"* ***OR*** *"Oral: low/lower «bioavailability» **AND** intraveneous: high/higher «bioavailability»".*	

Question			Answers	Notes	Total
19.			*Any two of:* reduce fever/antipyretic ✓ anti-inflammatory ✓ anti-coagulant/reduces blood clotting/blood thinner ***OR*** prevent cardiovascular disease/stroke ✓	*Accept "prevents/reduces «risk of» heart attack" for M3.* *Accept "prevents heart disease" for M3.* *Accept "may reduce colon/colorectal cancer" for M3.*	**2 max**
20.			bacterial resistance «to older penicillin's/antibiotics» ✓ prevent penicillinase/beta-lactamase/enzyme in bacterium to deactivate/open penicillin/beta-lactam ring ✓	*Accept "antibiotic resistant bacteria" but **not** "antibiotic resistance" for M1.* *Accept "reduce allergic reactions from penicillin" for M2.* . *Award **[1 max]** for "increased efficiency/bioavailability"* ***OR*** *"increased stability in GIT".* *Do **not** accept "bacterial tolerance".*	**2**

Question			Answers	Notes	Total
21.			«temporarily» binding to receptors in the nervous system/spinal cord/brain ✓ preventing transmission of pain impulses ✓	*Accept "bonding" for "binding" in M1.* *Accept "without depressing the central nervous system" for M2.*	**2**

22.	**(a)**	**(i)**	$Al(OH)_3(s) + 3HCl(aq) \rightarrow AlCl_3(aq) + 3H_2O(l)$ ***OR*** $Al(OH)_3(s) + 3H^+(aq) \rightarrow Al^{3+}(aq) + 3H_2O(l)$✓		**1**
22.	**(a)**	**(ii)**	«100 cm^3 / 1000 cm^3 x $5.00x10^{-3}$ mol dm^{-3} = » $5.00x10^{-4}$ «mol HCl» ✓ «$5.00x10^{-4}$ mol HCl /3 x 78.01 g mol^{-1} $Al(OH)_3$ = » 0.0130 «g $Al(OH)_3$» ✓	*Award **[2]** for correct final answer.*	**2**
22.	**(b)**		blocks/binds to H2/histamine receptors «in cells of stomach lining» ***OR*** prevents histamine binding to H2/histamine receptors «and triggering acid secretion» ✓ prevents «parietal cells from» releasing/producing acid ✓	*Do **not** accept "antihistamine" by itself.* *Accept "H2-receptor antagonist/H2RA"* ***OR*** *"blocks/inhibits action of histamine" for M1.* *Do **not** accept "blocks receptors" alone for M1.* *Do **not** accept "proton pump/ATPase inhibitor".*	**2**

Question			Answers	Notes	Total
23.			*Any two of:* alters «viral» enzyme ***AND*** prevent virus from entering the cell ✓. alter the cell DNA ***AND*** virus cannot multiply ✓ block «cell» enzyme activity ***AND*** prevent virus multiplication ✓ alters «viral» enzyme ***AND*** prevents release of «new» viral particles «from the cell» ✓	*Do **not** accept "just interferes with viral reproductive cycle".* *Award **[1 max]** for two partial answers.*	**2 max**

24.			high-level has large amounts of «ionizing» radiation ✓ high-level has long half-lives ***OR*** high-level last longer/persists ✓	*Accept converse statements for low-level.* *Accept "high radioactivity for high-level" for M1.* *Do **not** accept "high-level has ionizing radiation" alone for M1.* *Do **not** accept answers based on storage or disposal differences alone.* *Accept "high-level releases heat" for M2.* *Do **not** accept "high-level has more penetrating radiation"* ***OR*** *"high-level has higher frequency radiation" for M1.*	**2**

Question			Answers	Notes	Total
25.			bark of yew tree ✓ kills tree ***OR*** tree grows slowly ***OR*** low yield ✓	*Accept "Taxus brevifolia" for "yew tree".* *Do **not** accept "yew tree" alone for M1.*	**2**

26.	**(a)**		$^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\beta$ ✓	*Accept "e/e⁻/β for beta particle.* *Penalize incorrect Z even if elemental symbol is correct.* *Penalize incorrectly placed A and Z on nuclear symbol.* *Do **not** penalize missing Z on nuclear symbol.*	**1**

26.	**(b)**		radiation source delivered directly to cancer cells ✓ by a carrier drug/protein/antibody ✓ several sites in body can be targeted «at same time» ✓	*Accept "radioisotope «selectively» absorbed by cancer cells" **OR** "targeted to cancer cells" for M1.* *Reference to "cells" required in M1.*	**3**

Question			Answers	Notes	Total
27.	**(a)**		*Any three of:* $CH_3CH_2OH^+$ ✓ $CH_3CH_2^+$ ✓ CH_3^+ ✓ CH_2OH^+/CH_3O^+ ✓ OH^+ ✓	*Penalize missing charge once only.* *Accept any other reasonable fragments or m/z values.*	**3 max**
27.	**(b)**		*Any two of:* ethanoic acid ✓ chromium(III) ✓ water ✓	*Accept "ethanal" for M1.* *Accept correct name or formula.* *Accept systematic name or preferred IUPAC name (e.g. "acetic acid"* ***OR*** *"acetaldehyde").* *Accept any chromium(III) salt for M2.*	**2 max**

Question			Answers	Notes	Total
28.	**(a)**		*Any one of:* «most are» toxic «to living organisms» ***OR*** incomplete combustion/incineration can produce toxic products/dioxins/phosgene ***OR*** carcinogenic ✓ «some can be» greenhouse gases ✓ ozone-depleting ✓ can contribute to formation of «photochemical» smog ✓ accumulate in groundwater ***OR*** have limited biodegradability ✓ cost/hazards of disposal ✓	*Do **not** accept "harmful to the environment".* *Do **not** accept just "pollutes water".* *Do **not** accept "increases acid rain/acidity/acid deposition".*	**1 max**
28.	**(b)**		use solvent-free synthetic methods ***OR*** use water/supercritical carbon dioxide/non-toxic/low-toxic/biodegradable compounds as a solvent ***OR*** recover/reuse solvents ***OR*** use a non-chlorinated solvent ✓	*Accept arguments based on atom economy.* *Do **not** accept "use solvents safer for environment" alone.*	**1**