Markscheme

May 2024

Chemistry

Standard

Paper 3

25 pages

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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 underlined 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**		a leak «of gas from the system» ✓	*Accept amount/volume/concentration H_2O_2 much lower.* *Do **not** accept answers that refer to MnO_2.*	**1**
1.	**b**	**i**	scientific claims must be falsifiable ***OR*** it should be possible to test a scientific prediction by an experiment ✓	*Accept answers that imply this principle such as if hypothesis not supported underlying theory needs to be examined.*	**1**
1.	**b**	**ii**	doubling mass will double surface area ✓ «doubling surface area will» double collision rate / frequency of collisions ✓	*Accept increasing instead of doubling for both M1 and M2.* *Do **not** accept more/greater probability/chance of collisions.*	**2**
1.	**b**	**iii**	temperature ***OR*** concentration «of hydrogen peroxide»/[H_2O_2] ✓	*Accept different specific surface area / particle size.* *Do **not** accept simply surface area.*	**1**
1.	**c**	**i**	tangent drawn to curve at t = 0 s ✓ slope/gradient calculation ✓	*Accept start of reaction for t=0 s for M1.* *Do not accept line instead of tangent for M1.* *Do **not** accept simply taking a derivative for M2.*	**2**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**c**	**ii**	yes ***AND*** rate is negligible when no catalyst is present ***OR*** no ***AND*** reaction still occurs even when no catalyst is present ✓	*Accept* yes ***AND*** *rate is zero when no catalyst is present.* *Do* ***not*** *accept yes* ***AND*** *the line gives a better fit with the data.*	**1**

Question			Answers	Notes	Total
2.	a		**ALTERNATIVE 1** $n(CuSO_4) \text{«}= \frac{6.4\text{ g}}{(63.55+32.07+(4\times16.00))\text{g mol}^{-1}} = \frac{6.4\text{ g}}{159.62\text{ g mol}^{-1}}$ » = 0.040 «mol» ***AND*** $n(H_2O) \text{«} = \frac{(10.0-6.4)\text{ g}}{(2\times1.01)+16.00\text{ g mol}^{-1}} = \frac{3.6\text{ g}}{18.02\text{ g mol}^{-1}}$»= 0.20 «mol» ✓ $n(CuSO_4)$: $n(H_2O)$ «= $\frac{0.20\text{ mol}}{0.04\text{ mol}}$» = 5.0 ✓ **ALTERNATIVE 2** % $CuSO_4$ in $CuSO_4$•$5H_2O$ «$= 100\times\frac{63.55+32.07+(4\times16.00)\text{ g mol}^{-1}}{63.55+32.07+(9\times16.00)+(10\text{x}1.01)\text{ g mol}^{-1}} = \frac{15962\text{ g mol}^{-1}}{249.72\text{ g mol}^{-1}}$» = 63.92 ✓ mass of $CuSO_4$ «$= 10.0\text{ g}\times\frac{63.92}{100}$» = 6.392 g ✓ **ALTERNATIVE 3** mass of H_2O in $CuSO_4$•$5H_2O$ «$= 10\text{ g}\times\frac{(5\times16.00)+(10\times1.01)\text{ g mol}^{-1}}{(63.55+32.07+(9\times16.00)+(10\times1.01))\text{g mol}^{-1}} = \frac{900.1\text{ g}}{249.72}$» = 3.6 g ✓ mass of $CuSO_4$ in $CuSO_4$•$5H_2O$ «= 10.0 g – 3.6 g» = 6.4 g ***OR*** comparison with graph shows mass lost is 3.6 g ✓	*Accept other valid methods.*	**2**

(continued…)

(Question 2 continued)

Question			Answers	Notes	Total
2.	**b**	**i**	uncertainty in mass loss «$= 0.05 + 0.05$» = «±»0.1 g ✓ percentage uncertainty in mass loss «$= \frac{0.1\,\text{g}}{(10.0 - 6.4)} \times 100$» = «±»2.78 / 3 % ✓	*Award **[2]** for correct final answer.* *Accept 2.77.*	**2**
2.	**b**	**ii**	absolute uncertainty in water of crystallization «$= 5 \times \frac{2.78}{100}$» = «±»0.14 ✓	*Accept «±»0.15 if percentage uncertainty taken as 3%.* *Do **not** award marks for answers with more or less significant figures.*	**1**
2.	**c**		water molecules in different «chemical» environments ***OR*** water molecules have different type of bonding ✓ present in a 4:1 / 1:4 ratio ✓	*Do **not** accept different kinds of water molecules.* *Accept answers that clearly communicate the ratio.*	**2**

Section B

Option A — Materials

Question			Answers	Notes	Total
3.	**a**	**i**	electronegativity difference ΔX«$= 3.2 - 0.8$» $= 2.4$ ***AND*** average electronegativity $\sum X$ «$=\frac{1}{2}(3.2+0.8)$» $= 2.0$ ✓ falls in “ionic” region of bonding diagram ✓	*Accept 75% ionic and 25% covalent for M2.* *Do **not** accept ionic without reference to diagram.*	**2**
3.	**a**	**ii**	electrostatic attraction ***OR*** attraction between oppositely charged ions ✓	*Do **not** accept ionic.*	**1**
3.	**a**	**iii**	«small» displacement brings ions of same charge close together ***OR*** «small» displacement results in repulsion «between same charged ions» ✓	*Do **not** accept bonds are weak.*	**1**
3.	**b**		all electrons are paired/have paired spins ✓		**1**
3.	**c**	**i**	«caesium» very reactive / very high in reactivity series ***OR*** cannot be reduced by chemical methods ✓	*Do **not** accept simply caesium is reactive.* *Accept difficult to reduce «caesium ions».* *Accept Cs is higher on activity series than C.*	**1**

(continued…

(Question 3 continued)

Question			Answers	Notes	Total
3.	**c**	**ii**	$Cs^+(l) + e^- \rightarrow Cs(l)$ ✓		**1**
3.	**c**	**iii**	amount of Cs «$= \frac{1.00\ g}{132.91\ g\ mol^{-1}}$» = 0.00752 «mol» ✓ charge «= 0.00752 mol × 9.65 × 10^4 C mol^{-1}» = 726«C» ✓	*Accept 0.007 for M1.* *Award **[2]** for correct final answer.*	**2**
3.	**d**	**i**	***Similarity:*** *Any one of:* increase rate of reaction ✓ provide an alternative mechanism ✓ reduce activation energy/E_a «for the reaction» ✓ not consumed «in overall reaction» ✓ ***Difference:*** *Any one of:* heterogeneous are in different phase to reactants ***AND*** homogeneous in same phase ✓ heterogeneous are solids ***AND*** homogeneous are fluids/liquids/gases/ in solution ✓ heterogeneous act on surface ***AND*** homogeneous act in fluid/medium ✓ heterogeneous remain unchanged ***AND*** homogeneous consumed at one stage and regenerated at another ✓ heterogeneous more easily removed «from product than homogenous» ✓	*Accept state for phase.*	**2**
3.	**d**	**ii**	«very» large surface area «to mass ratio» ✓		**1**
3.	**d**	**iii**	prevents oxidation ✓	*Accept prevents reaction with air.*	**1**

(continued…)

(Question 3 continued)

Question			Answers	Notes	Total
3.	**d**	**iv**	negative effect on/harmful to environment/human health ✓	*Accept uncertain effect on human health.* *Do **not** award mark for poisonous/toxic.*	**1**

Question			Answers	Notes	Total
4.	**a**		increase flexibility ✓ reduce intermolecular forces between «polymer» chains ✓	*Accept increase softness / reduce density / make less brittle for M1.* *Accept increase distance between chains for M2.* *Accept allow chains to slide past each other more easily for M2.*	**2**

(continued…)

(Question 4 continued)

Question			Answers	Notes	Total
4.	**b**		*Class:* «polychlorinated dibenzo» dioxin«s» ✓ *Effect:* hormone disrupting/disrupts metabolic processes ***OR*** cellular damage ***OR*** genetic damage ***OR*** carcinogenic ✓	*Do **not** accept toxic (given in question stem for M2).*	**2**
4.	**c**	**i**	«facilitates sorting for» recycling ✓		**1**
4.	**c**	**ii**	A ***AND*** it has C=O/~1700 «cm^{-1}» absorption ✓	*Accept A **AND** B has* C–Cl/~700 «cm^{-1}» *absorption.*	**1**

Option B — Biochemistry

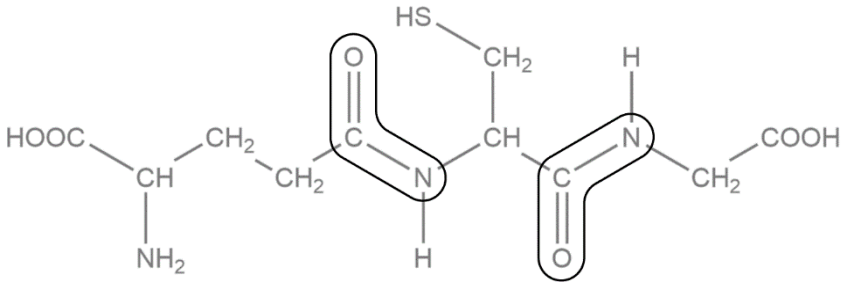
Question			Answers	Notes	Total
5.	**a**		$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$ ✓	*Ignore light in the equation.*	**1**
5.	**b**	**i**	*Type of reaction:* condensation ***AND*** *By-product:* water ✓	*Accept addition–elimination for Type of reaction.*	**1**
5.	**b**	**ii**	insoluble «in water»/cytoplasm ✓	*Accept stored as solid grains.*	**1**
5.	**b**	**iii**	hydrolyze ✓	*Accept convert back to glucose.* *Accept break down starch «into smaller units/components/monomers».*	**1**

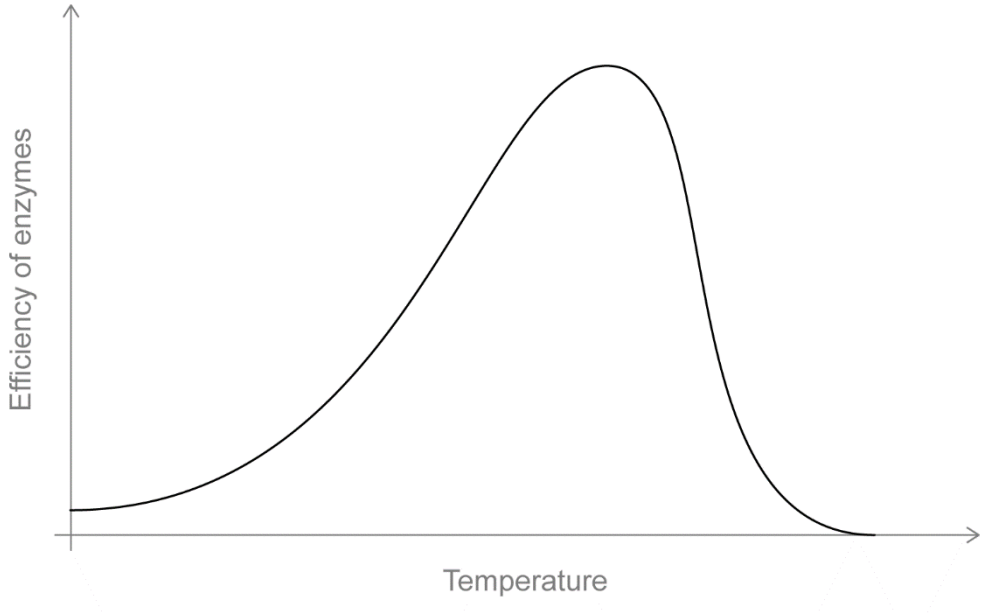
Question			Answers	Notes	Total
6.	**a**		corn oil ***AND*** highest content of polyunsaturated fatty acids ***OR*** corn oil ***AND*** highest number of C=C/double bonds «per molecule/triglyceride» ✓	*Do **not** accept least saturated/most unsaturated.*	**1**
6.	**b**		«$n(I_2) = 0.0330\ dm^3 \times 0.500\ mol\ dm^{-3}$ =» 0.0165 «mol» ✓ «$m(I_2) = 0.0165\ mol \times 253.8\ g\ mol^{-1}$ =» 4.19 «g» ✓ «iodine number $= \frac{4.19\ g \times 100}{5.00\ g}$ » = 83.8 ✓	*Award **[3]** for correct final answer.* *Award **[2 max]** for 41.9.*	**3**

(continued…)

(Question 6 continued)

Question			Answers	Notes	Total
6.	**c**		higher proportion of «triglycerides of» saturated fatty acids ***OR*** saturated fatty acids have greater surface area/higher electron density ***OR*** molecules of «triglycerides of» saturated fatty acids are packed more closely/have a linear structure ✓ stronger London/dispersion/instantaneous induced dipole-induced dipole forces **«**between linear chains**»** ✓	*For M1 do **not** accept butter is saturated without reference to proportions.* *For M2 accept stronger intermolecular forces.* *Accept LDF for London dispersion forces*	**2**

Question			Answers	Notes	Total
7.	**a**		 correct identification of both bonds ✓	*Accept circle including H.*	**1**
7.	**b**		glycine/gly ***AND*** glutamic acid/glu ***AND*** cysteine/cys ✓	*Accept structures.* *Accept in any order.*	**1**
7.	**c**		glycine/gly ✓	*Accept structure.*	**1**

Question			Answers	Notes	Total
8.	**a**	**i**	 typical curve as shown ✓	*Accept any curve with a single maximum.* *Ignore other annotations, such as temperature values on the x-axis.* *Do **not** penalize if curve does not touch the x-axis at high temperature.*	**1**

(continued…)

(Question 8 continued)

Question			Answers	Notes	Total
8.	**a**	**ii**	*Low temperature:* molecules collide less frequently ***OR*** molecules have insufficient/low «kinetic» energy «to overcome E_A» ✓ *High temperature*: enzymes are denatured ***OR*** tertiary structure disrupted ✓	*For M1 accept low reaction rate.* *For M1 do **not** accept more/ greater probability/chance of collisions.* *Accept enzymes break down/decompose for M2.*	**2**
8.	**b**		partial replacement of «non-/scarcely biodegradable» detergent by biodegradable enzymes ***OR*** save energy as require lower temperature ***OR*** biodegradable ✓	*Do **not** accept references to eutrophication, phosphates, nitrates, etc.* *Accept break down naturally.*	**1**
8.	**c**		*Award **[1]** for any of*: «treatment of» oil spills ✓ «treatment of harmful» effluents from sewage/paper mills/leather processing/textile industry/food industry ✓	*Accept other reasonable examples.* *Do **not** accept plastics.*	**1**

Question			Answers	Notes	Total
9.			«many» OH/hydroxyl «groups» ✓ can H-bond to water ✓	*Accept alcohol/hydroxy, but **not** hydroxide for hydroxyl.*	**2**

Option C — Energy

Question			Answers	Notes	Total
10.	**a**		$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ ✓		**1**
10.	**b**		«specific energy $= \frac{891\,\text{kJ mol}^{-1}}{16.05\,\text{g mol}^{-1}} =$» 55.5 «kJ g^{-1}» ✓	*Accept 55.7 «kJ g^{-1}» if integer atomic masses used.* *Do **not** accept –55.5 «kJ g^{-1}».*	**1**
10.	**c**		*Lower specific energy:* not all methane clathrate is methane ***OR*** part of methane clathrate does not burn ✓ *Higher energy density:* methane is gas ***AND*** methane clathrate is solid ***OR*** methane has much lower density «than methane clathrate» ***OR*** methane clathrate occupies a much smaller volume than «same mass of» methane ✓	*For M1 accept reference to water molecules in methane clathrate as indicating it is not all methane.*	**2**

(continued…)

(Question 10 continued)

Question			Answers	Notes	Total
10.	**d**		photosynthesis «in green plants to produce carbohydrates» ✓ reduction/anaerobic decay of carbohydrates/biological compounds/plant material «produced hydrocarbons like methane» ✓	*Accept balanced equation for photosynthesis.* *For M2 accept geological processing converted plant material into methane.* *For M2 accept digestive processes convert carbohydrates to methane.*	**2**
10.	**e**		asymmetric «stretch» ***AND*** produces/changes dipole moment ✓		**1**
10.	**f**		methane more potent greenhouse gas/higher GWP than carbon dioxide «produced by burning it» ✓	*Accept answers that imply we could be harnessing the energy released by the combustion.*	**1**

(continued…)

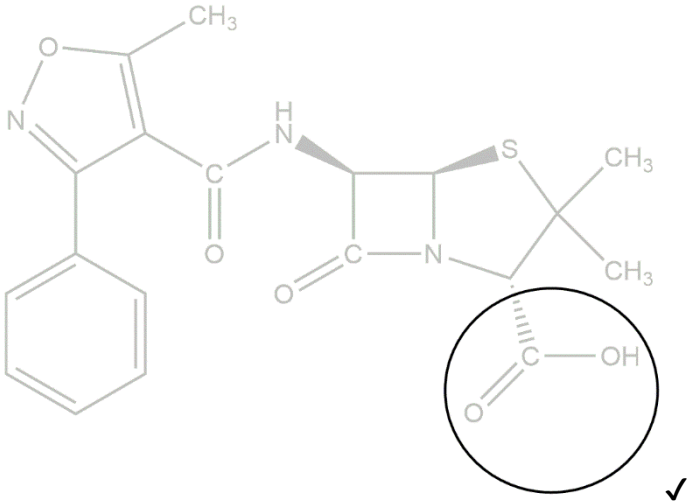
(Question 10 continued)

Question			Answers	Notes	Total
10.	**g**		*Support:* overall increase in both the carbon dioxide concentration and the temperature «anomaly» ✓ *Refute:* CO_2 increases between ~1940 and ~1970 without corresponding increase in temperature ***OR*** global temperatures rose between ~1935 and ~1945 despite [CO_2] remaining relatively constant ***OR*** increases in global temperature between ~1900 and ~1940 and between ~1970 and ~2010 are similar, but increase in CO_2 levels much higher in latter period ✓	*For M1, accept there is a good/close correlation «in their shapes».* *For M2, accept the connection may just be coincidental «not causative».* *Do **not** accept comments about fluctuations.* *Accept years that are approximately the same as these listed.*	**2**

Question			Answers	Notes	Total
11.	**a**	**i**	methane produces less CO_2 per kJ of energy ✓ methane produces fewer pollutants/particulates/CO/VOCs ✓	*For M1 do **not** accept simply methane produces less CO_2.* *For M2 accept gasoline undergoes incomplete combustion.*	**2**
11.	**a**	**ii**	greater energy density ***OR*** longer range «for same volume of fuel»/requires smaller fuel tank ✓	*Accept more concentrated source of energy.* *Accept greater distance between refuelling.* *Accept gasoline more readily available.* *Accept gasoline fuelled cars safer / have lower explosion/auto-ignition risk.* *Accept gasoline easier to handle / store / transport.*	**1**
11.	**b**	**i**	**A:** CH_3OH ***AND*** **B:** $CH_3–O–CO–R$ ***OR*** **A:** C_2H_5OH ***AND*** **B:** $C_2H_5–O–CO–R$ ✓	*Accept R-OH/R'-OH **AND** R-O-CO-R/R'-O-CO-R.* *Do **not** accept names.*	**1**
11.	**b**	**ii**	low«er» viscosity ✓ «simple esters have» weaker London/dispersion forces «than vegetable oils» ✓	*Do **not** accept intermolecular forces or van der Waals' forces instead of London/dispersion forces.*	**2**

Question			Answers	Notes	Total
12.	**a**		*Similarity:* both convert mass into energy ***OR*** both increase the binding energy «per nucleon» ✓ *Difference:* fusion «two smaller/lighter» nuclei combine «to produce a larger/heavier one» ***AND*** fission «heavy» nucleus splits «into fragments/smaller/lighter nuclei» ✓	*For similarity accept that mass is lost/mass of products is less than that of reactants.* *For similarity accept change of atomic number / new elements produced.* *Do **not** accept atoms/s instead of nucleus/i.*	**2**
12.	**b**		«dark» lines in spectrum of sunlight ✓	*Do **not** accept simply spectrometry/spectroscopy.* *Do **not** accept references to emission spectra.*	**1**
12.	**c**		«nuclear reactor technology can be adapted for» nuclear weapons «production» ✓	*Do **not** accept geopolitical reasons.*	**1**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
13.	**a**		interfere with «bacteria» cell wall ***OR*** animal cells do not have a cell wall ✓	*Do **not** accept transpeptidase without reference to cell wall.*	**1**
13.	**b**	**i**	«bulky group/steric shield» prevents enzyme/penicillinase/beta-lactamase attacking β-lactam ring ✓	*Accept harder for penicillinase to access/reach β-lactam ring.* *Accept shields/increases stability of β-lactam ring.*	**1**
13	**b**	**ii**	 ✓	*Circle must enclose the whole of the COOH group.*	**1**

(continued…)

(Question 13 continued)

Question			Answers	Notes	Total
13.	**c**		«low doses of» antibiotics reach the water/soil/animal waste ***OR*** «low doses of» antibiotics are present in the animals / food produced from animals ✓ favours survival/spread of mutant/resistant bacteria ✓	*Do **not** accept increased probability of mutation for M2.*	**2**

Question			Answers	Notes	Total
14.	**a**	**i**	*Any one of:* addiction/dependency ✓ decreased breathing-rate ✓ decreased heart rates ✓ constipation ✓ reduced sex drive ✓ loss of appetite ✓ depression ✓	*Do **not** accept vague responses such as suppression/decrease in brain activity.*	**1**
14.	**a**	**ii**	need to increase dose of opiates for the same effect ✓	*Do **not** accept just body adapts to action of the drug.* *Do **not** accept just less effective.*	**1**
14.	**b**	**i**	«phenolic» OH/hydroxyl replaced by OCH_3/ether/methoxy group ✓	*Accept methylated.* *Accept alcohol/hydroxy, but **not** hydroxide for hydroxyl.*	**1**

(continued…)

(Question 14 continued)

Question			Answers	Notes	Total
14.	**b**	**ii**	codeine has fewer OH/hydroxyl groups «than morphine» ✓ can cross the blood-brain barrier more easily ✓	*Accept codeine is more lipid soluble / less polar «than morphine» for M1.*	**2**

Question			Answers	Notes	Total
15.	**a**		anticoagulant/prevention of blood clots ✓	*Accept blood thinner / reducing chance/incidence of strokes/heart attacks.*	**1**
15.	**b**		synergistic effect ***OR*** increases anticoagulant effect ✓	*Accept the effect of one reinforces the effect of the other.* *Accept increased «risk of» stomach/gastrointestinal bleeding.*	**1**

Question			Answers	Notes	Total
16.	**a**		$Al(OH)_3(s) + 3HCl(aq) \rightarrow AlCl_3(aq) + 3H_2O(l)$ ✓	*Accept equations with $H^+(aq)$ rather than $HCl(aq)$.*	**1**
16.	**b**		inhibits enzyme/H^+ K^+–ATPase /gastric proton pump which secretes H^+ **«**ions into gastric juice**»** ✓	*Accept proton pump inhibitor/PPI.*	**1**

(continued…)

(Question 16 continued)

Question			Answers	Notes	Total
16.	**c**		$pH - pK_a = \log \frac{[HCO_3^-]}{[H_2CO_3]} = 1.12$ ✓ $[HCO_3^-] = «13.18 \times 2.03 \times 10^{-3} =» 2.68 \times 10^{-2}$ «mol dm^{-3}» ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
17.	**a**		*Any one of:* «viruses» lack cellular structure ✓ do not have their own metabolism ✓	*Do **not** accept simply lack of cell wall. Accept viruses have a «protein» capsid rather than a cell wall.*	**1 max**
17	**b**	**i**	**«**drug**»** blocks/inhibits **«**viral**»** enzyme/neuraminidase/NA **«**activity**»** ✓ prevents virus from leaving/escaping host cells **«**thus cannot infect other cells**»** ✓		**2**
17	**b**	**ii**	zanamivir ***AND*** many OH/hydroxyl/NH/NH_2 groups «that can H-bond with water» ✓	*Accept alcohol/hydroxy, but **not** hydroxide for hydroxyl.*	**1**