Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2020

Chemistry

Standard level

Paper 3

30 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 **[20marks]**.
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		oil is non-polar «and dissolves best in non-polar solvents» ***OR*** oil does not dissolve in polar solvents ✓	*Do **not** accept "like dissolves like" only.*	1
1.	b		solvent/oil is flammable ***OR*** solvent/oil must be kept below its flash point ***OR*** oxidation/decomposition of oil ***OR*** mixture has a low boiling point ✓	*Accept "to prevent evaporation of oil".*	1
1.	c		distillation «instead of evaporation» ✓	*Accept "pass vapour through a condenser and collect liquid".* *Do **not** accept "condensation" without experimental details.*	1

Question			Answers	Notes	Total
1.	**d**		*Experimental mass greater than actual mass of oil in crisps:* other substances **«**in the crisps**»** are soluble in the solvent ***OR*** not all the solvent evaporates ✓ *Experimental mass less than actual mass of oil in crisps:* not all oil dissolved/extracted✓	*Accept "oil evaporated" **OR** "oil burned/decomposed" **OR** "oil absorbed by the filter" **OR** "assumption **«**all oil dissolved**»** was wrong" for M2.* *Do **not** accept examples of human errors **OR** faulty apparatus.*	**2**

Question			Answers	Notes	Total
2.	**a**		*Independent variable*: chain length ***OR*** number of carbon **«**atoms in alcohol**»** ***AND*** *Dependent variable:* volume of NaOH ***OR*** K_c/equilibrium constant ***OR*** equilibrium concentration/moles of CH_3COOH ✓		**1**
2.	**b**		dilution/lower concentrations ✓ less frequent collisions **«**per unit volume**»** ✓	*Accept "lowers concentration of acid catalyst" for M1. M2 must refer to increase in activation energy or different pathway.* *Do **not** accept responses referring to equilibrium.*	**2**
2.	**c**		equilibrium shifts to left ***OR*** more ethanoic acid is produced **«**as ethanoic acid is neutralized**»** ***OR*** prevents/slows down ester hydrolysis ✓	*Accept "prevents equilibrium shift" if described correctly without direction.*	**1**
2.	**d**		to determine volume/moles of NaOH used up by the catalyst/sulfuric acid **«**in the titration**»** ***OR*** to eliminate/reduce **«**systematic**»** error caused by acid catalyst ✓	*Do **not** accept "control" **OR** "standard" alone.*	**1**

Question			Answers	Notes	Total
2.	**e**		*Percentage uncertainty:* **«** $\frac{0.4 \times 100}{6.5} =$ **»** 6 **«**%**»** ✓ *Percentage error:* **«** $\frac{6.5 - 5.3}{5.3} \times 100 =$ **»** 23 **«**%**»** ✓	*Award **[1 max]** if calculations are reversed **OR** if incorrect alcohol is used.*	**2**
2.	**f**		*Any two:* large percentage error means large systematic error **«**in procedure**»** ✓ small percentage uncertainty means small random errors ✓ random errors smaller than systematic error ✓	*Award [**2**] for "both random and systematic errors are significant."*	**2 max**
2.	**g**		corrosive/burns/irritant/strong oxidizing agent/carcinogenic ***OR*** disposal is an environmental issue ***OR*** causes other side reactions/dehydration/decomposition ✓	*Do **not** accept just "risk of accidents" **OR** "health risks" **OR** "hazardous".*	**1**

Section B

Option A — Materials

Question			Answers	Notes	Total
3.	a		carbon fibre reinforcing phase ✓ **«**in a**»** matrix phase of epoxy ✓	*Award **[1 max]** for "reinforcing phase **«**embedded**»** in a matrix".*	**2**
3.	b	i	can be recycled ***OR*** can be reformed when hot ***OR*** high impact/chemical/abrasion resistance ✓		**1**
3.	b	ii	*Any three of:* plasticizers embed/fit between **«**polymer**»** chains ✓ keep polymer strands/chains/molecules separated/apart ✓ weaken intermolecular/London/dispersion/attractive/forces/instantaneous induced dipole-induced dipole/forces **«**between chains**»** ✓ prevent chains from packing closely/forming regular packing/structure ✓	*Accept "van der Waals/vdW" for "London".*	**3 max**

Question			Answers	Notes	Total
3.	**c**		*Any two of:* readily released into environment ***OR*** have weak intermolecular forces **«**rather than covalent bonds between chains**»** ✓ get into biological systems by ingestion/inhalation ✓ interrupt endocrine systems ***OR*** affect release of hormones ***OR*** effect development of male reproductive system ✓ considered carcinogenic ***OR*** can cause cellular damage ✓ can cause early puberty in females ✓ can cause thyroid effects ✓ can cause asthma ✓	*Do **not** accept just "are a health concern".*	**2 max**

Question			Answers	Notes	Total
4.	**a**		*Excellent strength:* defect-free ***AND*** rigid/regular 2D/3D ✓ *Excellent conductivity:* delocalized electrons ✓	*Accept "carbons/atoms are all covalently bonded to each other" for M1.*	**2**
4.	**b**	**i**	*Any of:* ductility ✓ strength/resistance to deformation ✓ malleability ✓ hardness ✓ resistance to corrosion/chemical resistance ✓ range of working temperatures ✓ density ✓	*Do **not** accept "conductivity".*	**1**
4.	**b**	**ii**	Anode: $2Cl^- \rightarrow Cl_2(g) + 2e^-$ ✓ Cathode: $Mg^{2+} + 2e^- \rightarrow Mg(l)$ ✓	*Accept $Cl^- \rightarrow Cl_2(g) + e^-$.* *Award **[1 max]** for correct equations at incorrect electrodes.*	**2**

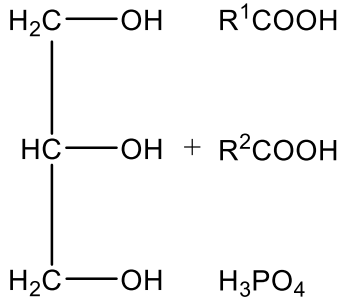
(continued…)

(Question 4b continued)

4.	**b**	**iii**	«$Q = I \times t = 3.00 \times 10.0 \times 3600 =$» 108 000 C ✓ «$\frac{Q}{F} = \frac{108\,000\ C}{96\,500\ C\ \text{mol}^{-1}}$ =» 1.12 «mol e^-» ✓ «$\frac{1.12\,\text{mol}}{2} = 0.560\,\text{mol Mg}$» «$m = 0.560\,\text{mol} \times 24.31\,\text{g mol}^{-1}$ =» 13.6 «g» ✓	*Award **[3]** for correct final answer.*	**3**
4.	**b**	**iv**	argon/Ar/helium/He ✓	*Accept any identified noble/inert gas.* *Accept name **OR** formula.* *Do **not** accept "nitrogen/N_2".*	**1**
4.	**c**		pores/cavities/channels/holes/cage-like structures ✓ «only» reactants with appropriate/specific size/geometry/structure fit inside/go through/are activated/can react ✓	*Accept "molecules/ions" for "reactants" in M2.*	**2**
4.	**d**		rod-shaped molecules ***OR*** «randomly distributed but» generally align ***OR*** no positional order ***AND*** have «some» directional order/pattern ✓	*Accept "linear" for "rod-shaped".*	**1**

Option B — Biochemistry

Question			Answers	Notes	Total
5.	**a**	**i**	0.70 ✓	*Accept any value within the range "0.67–0.73".*	**1**
5.	**a**	**ii**	Ile ***AND*** larger R_f ✓ more soluble in non-polar solvent **«**mobile phase**»** ***OR*** not as attracted to polar **«**stationary**»** phase ✓	*Only award M2 if Ile is identified in M1.*	**2**
5.	**b**		hydrogen/H bonding **«**between amido hydrogen and carboxyl oxygen atoms**»** ✓		**1**
5.	**c**		tertiary: folding/shape of a single «polypeptide/protein» chain ✓ quaternary: arrangement/folding of four/several chains/proteins/polypeptides «held together by IMF» ✓	*Accept "two or more polypeptides" for M2.*	**2**

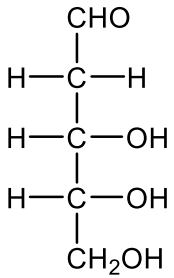
Question			Answers	Notes	Total
6.	**a**		 glycerol ✓ both fatty acids ***AND*** phosphoric acid ✓	*Accept either names **OR** structures.* *Accept "long chain carboxylic acid" for "fatty acid".* *Penalise once only if an incorrect name is given for a correct structure or vice-versa.*	**2**
6.	**b**	**i**	***A**:* phosphate/ionic group ***AND*** ***B***: alkyl/hydrocarbon **«**chain**»** ✓	*Accept "glycerol **«**fragment**»**" **OR** "glycerophosphate" **OR** "ester" for **A**.* *Accept "fatty acid **«**tail**»**" for **B**.* *Do **not** accept terms such as "polar head", "non-polar tail", "hydrophilic" **OR** "hydrophobic" for components alone.*	**1**

(continued…)

(Question 6b continued)

Question			Answers	Notes	Total
6.	**b**	**ii**	*Forces occurring between components labelled **A**:* hydrogen/H bonding ***OR*** ion–dipole ***OR*** ionic/electrostatic **«**repulsion and/or attraction**»** ✓ *Forces occurring between components labelled **B**:* dispersion/London/instantaneous dipoles/temporary dipoles ✓	*Accept "dipole-dipole" for M1.* *Do **not** accept "van der Waals/vdW" for M1.* *Accept "van der Waals/vdW" for M2.*	**2**

Question			Answers	Notes	Total
6.	**c**		*Energy storage:* not water-soluble/no hydrogen/H bonding ***OR*** less oxidized/more reduced ***OR*** high energy stored in bonds ***OR*** high «negative» enthalpy of combustion/oxidation ✓ *Electrical insulator:* no delocalized electrons/conjugation ✓	*Accept "potential energy" for "stored energy".*	**2**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>7.</td><td>a</td><td></td><td>
<table>
<tr><th>Vitamin</th><th>Soluble in</th></tr>
<tr><td>A</td><td>fat</td></tr>
<tr><td>C</td><td>water</td></tr>
<tr><td>D</td><td>fat</td></tr>
</table>
all three correct ✓</td><td></td><td>1</td></tr>
<tr><td>7.</td><td>b</td><td>i</td><td> 

–CH_2– must be placed next to CHO AND 2OH’s on central carbons must be on same side (LHS or RHS) ✓</td><td>Accept crosses in place of C on three middle carbons.</td><td>1</td></tr>
<tr><td>7.</td><td>b</td><td>ii</td><td>Reaction type:
condensation ✓

Functional group:
acetal/ether/glycosidic «linkage» ✓</td><td>Accept “nucleophilic substitution/S_N” for M1.

Accept “glycoside” for M2.</td><td>2</td></tr>
</table>

Question			Answers	Notes	Total
8.	**a**		«0.3 μg × 2000 =» 600 «μg X» ✓ « $\frac{600\,\mu g}{120\,kg}$ / $0.3\,\mu g\,kg^{-1}$ =» 17 ✓	*Award **[2]** for correct final answer.* *M2 may also be correctly expressed to 1 SF.*	**2**
8.	**b**		fat-soluble ***AND*** pass through lipid membranes/accumulate in cells/fatty tissues ***OR*** fat-soluble ***AND*** less easily excreted/metabolized ✓	*Accept "water-soluble" only if an organometallic–protein interaction is mentioned.*	**1**

Option C — Energy

Question			Answers	Notes	Total
9.	**a**		**«**21 200 kJ dm^{-3} × 5.00 dm^3 =**»** 106000/1.06 × 10^5 **«**kJ**»** ✓		**1**
9.	**b**		alkane ***OR*** cycloalkane ***OR*** arene ✓	*Accept "alkene".* *Do **not** accept just "hydrocarbon", since given in stem.* *Do **not** accept "benzene/aromatic" for "arene".*	**1**

Question			Answers	Notes	Total
9.	c		*Advantages:* ***[2 max]*** renewable ✓ uses up waste **«**such as used cooking oil**»** ✓ lower carbon footprint/carbon neutral ✓ higher flashpoint ✓ produces less SO_x/SO_2 ***OR*** less polluting emissions ✓ has lubricating properties ***OR*** preserves/increases lifespan of engine ✓ increases the life of the catalytic converter ✓ eliminates dependence on foreign suppliers ✓ does not require pipelines/infrastructure **«**to produce**»** ✓ relatively less destruction of habitat compared to obtaining petrochemicals ✓ *Disadvantages:* ***[2 max]*** needs conversion/transesterification ✓ takes time to produce/grow plants ✓	*Accept "higher energy density"* ***OR*** *"biodegradable" for advantage.* *Accept "lower specific energy" as disadvantage.*	**4**

			takes up land ***OR*** deforestation ✓ fertilizers/pesticides/phosphates/nitrates **«**used in production of crops**»** have negative environmental effects ✓ biodiversity affected ***OR*** loss of habitats **«**due to energy crop plantations**»** ✓ cannot be used at low temperatures ✓ variable quality **«**in production**»** ✔ high viscosity/can clog/damage engines ✔	*Do **not** accept "lower octane number" as disadvantage".*	

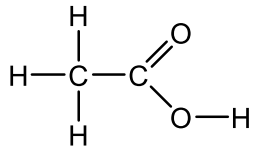
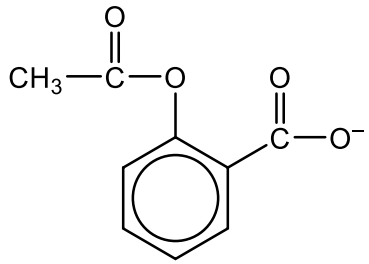
Question			Answers	Notes	Total
9.	**d**		*Any one:* uses up fossil fuels more slowly ✓ lower carbon footprint/CO_2 emissions ✓ undergoes more complete combustion ✓ produces fewer particulates ✓ higher octane number/rating ***OR*** less knocking ✓ prevents fuel injection system build up ***OR*** helps keep engine clean ✓	*Accept an example of a suitable advantage even if repeated from 9c.*	**1 max**
9.	**e**		*Any two:* biodiesel has smaller molecules/single «hydrocarbon» chain ***AND*** oil has larger molecules/multiple «hydrocarbon» chains ✓ biodiesel is methyl/ethyl ester ***AND*** oil has «backbone of» glycerol joined to fatty acids ✓ biodiesel contains one ester group ***AND*** oil contains three ester groups ✓	*Do **not** accept properties such as "less viscous" or "lower ignition point".*	**2 max**

Question			Answers	Notes	Total
9.	**f**	**i**	carbon dioxide allows sunlight/short wavelength radiation to pass through ***AND*** particulates reflect/scatter/absorb sunlight ✓	*Accept "particulates reflect/scatter/absorb sunlight **AND** carbon dioxide does not".* *Accept "CO_2 absorbs IR «radiation» **AND** particulates reflect/scatter/absorb sunlight".* *Do **not** accept "traps" for "absorbs".*	**1**
9.	**f**	**ii**	carbon dioxide is highly/more abundant **«**in the atmosphere**»** ✓ methane is more effective/potent **«**as a greenhouse gas**»** ***OR*** methane/better/more effective at absorbing IR **«**radiation**»** ***OR*** methane has greater greenhouse factor ***OR*** methane has greater global warming potential/GWP✓	*Accept "carbon dioxide contributes more to global warming" for M1.*	**2**
9.	**f**	**iii**	any value or range within 2850–3090 «cm^{-1}» ✓		**1**

Question			Answers	Notes	Total
10.	**a**		«$\frac{\text{mass \%}}{\text{fraction of U in } UO_2}$ = » $\frac{238.03}{238.03+2\times16}$ /0.881/88.1 % ✓ 46.5 **«**kg**»** × 0.0157 × 0.881 × 0.9928 **«**= 0.639 kg**»** ✓	*Award **[1 max]** for omitting mass composition (giving 0.725 kg).* *M2 is for numerical setup, **not** for final value of 0.639 kg.*	**2**
10.	**b**		***Alternative 1*** «$\frac{2.23\times10^{10}\text{ year}}{4.46\times10^{9}\text{ year}}$ = **»** 5.00 **«**half-lives**»** ✓ **«***m* = 0.639 kg × $(0.5)^5$ = **»** 0.0200 **«**kg**»** ✓ ***Alternative 2*** **«**$\lambda = \frac{\ln 2}{4.46\times10^{9}\text{ year}}$ = **»** 1.554×10^{-10} **«**year^{-1}**»** ✓ **«***m* = 0.639 kg × $e^{-1.554\times10^{-10}\,year^{-1}\times2.23\times10^{10}\,\text{year}}$ = **»** 0.0200 **«**kg**»** ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
10.	**c**		*Any one:* **«**genetic**»** mutations ✓ **«**could cause**»** cancer ✓ cells **«**in body**»** altered ✓ cells **«**in body**»** cannot function ✓ damaged DNA/proteins/enzymes/organs/tissue ✓ **«**radiation**»** burns ✓ hair loss ✓ damage in foetuses ✓ damages/weakens immune system ✓	*Accept specific named types of cancer.*	**1 max**
10.	**d**		$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$ ✓	*Do **not** penalize missing atomic numbers in the equation.* *Accept "α" for "He".*	**1**
10.	**e**		energy required to separate a nucleus into protons and neutrons/nucleons ***OR*** energy released when nucleus was formed from **«**individual/free/isolated**»** protons and neutrons/nucleons ✓	*Do **not** accept "energy released when atom was formed".*	**1**

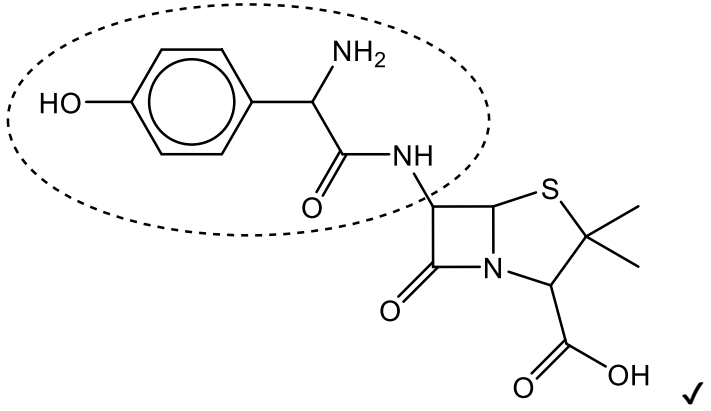
Option D — Medicinal chemistry

Question			Answers	Notes	Total
11.	**a**		 ***OR*** CH_3COOH ✓	*Accept full **OR** condensed structural formula.*	**1**
11.	**b**		to avoid dissolving the crystals/aspirin ✓	*Accept "to avoid loss of product" **OR** "aspirin is less soluble in cold water".*	**1**
11.	**c**		 ✓	*Accept a positive metal ion next to the COO^- such as "Na^+/K^+".* *Accept "–ONa/–OK" without showing the charges.* *Accept notations such as "$RCOO^-$" **OR** "RCOONa" **OR** "RCOOK" but **not "**RO^-" **OR** "RONa" **OR** "ROK".*	**1**

Question			Answers	Notes	Total
11.	**d**		low/medium risk **«**of overdosing**»** ***AND*** **«**estimated**»** lethal dose is 30 times/much larger than therapeutic dose ***OR*** 30 times the dose results in chance of dying ✓	*Accept "30 and low/medium risk due to large therapeutic index".* *Do **not** accept "low/medium risk **AND** large therapeutic window".* *Do **not** accept "30 times the dose" alone for the mark.*	**1**

Question			Answers	Notes	Total
12.			same reactant mole ratio **«**in both equations**»** ***OR*** $Mg(OH)_2(s) + 2HCl(aq)$ **«**$\rightarrow MgCl_2(aq) + 2H_2O(l)$ **»** ***AND*** $CaCO_3(s) + 2HCl(aq)$ **«**$\rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$**»** ✓ $n_{Mg(OH)_2} =$ **«** $\frac{0.200}{58.32}$ **=»** 3.43×10^{-3} **«**mol**»** ***AND*** $n_{CaCO_3} =$ **«** $\frac{0.220}{100.09}$ **=»** 2.20×10^{-3} **«**mol**»** ✓ **«**tablet of**»** X neutralizes 6.86×10^{-3} **«**mol**»** HCl ***AND*** **«**tablet of**»** Y neutralizes 4.40×10^{-3} **«**mol**»** HCl ✓	*Award **[3]** for correct final statement **AND** values in M3.*	**3**

Question			Answers	Notes	Total
13.	**a**		store until material becomes inactive/radiation levels drop ✓ dispose with other waste ***OR*** dispose in landfills ✓	*Only award M2 if M1 correct.* *Accept "dispose by incineration" for M2.*	**2**
13.	**b**		«use of» alternative solvents such as supercritical/liquid CO_2 ***OR*** use of water «as solvent» ***OR*** solvent-free reactions «for example, polymerization of propene» ***OR*** solid-state chemistry ***OR*** recycle «waste» solvents ***OR*** catalysis that leads to better/higher yield ***OR*** reducing number of steps ✓	*Do **not** accept political or regulatory solutions.* *"catalysis" alone not sufficient for mark.*	**1 max**

Question			Answers	Notes	Total
14.	**a**	**i**	*Any two:* «secondary» carboxamide/amido ✓ ether ✓ carbonyl ✓	*Accept amide* *Accept amino/amine.* *Accept alkenyl/alkene.* *Do **not** accept formula.*	**2 max**
14.	**a**	**ii**	**«**drug**»** blocks/inhibits **«**viral**»** enzyme/neuraminidase/NA **«**activity**»** ✓ prevents virus from leaving/escaping host cells **«**thus cannot infect other cells**»** ✓	*Do **not** accept other anti-viral methods (as question is specific to Zanamivir).*	**2**
14.	**b**	**i**	 ✓	*Accept a circle that does not surround the amido group.* *Do **not** accept a circle that only surrounds the phenol group.*	**1**

(continued…)

(Question 14b continued)

14.	**b**	**ii**	bacterial resistance **«**to older penicillins/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 from penicillin" for M2.* *Award **[1 max]** for "increased efficiency" **OR** "increased stability in GIT".* *Do **not** accept "bacteria develop tolerance".*	**2**
14.	**c**	**i**	codeine less soluble **«**in water**»** than morphine ***AND*** more soluble than diamorphine ***OR*** morphine > codeine > diamorphine **«**in terms of solubility in water**»** ✓ more/stronger/greater hydrogen/H bonding **«**due to more hydroxyl groups leads to greater solubility**»** ✓		**2**
14.	**c**	**ii**	opium poppy/plants/seeds ✓	*Accept "poppy" **OR** "opioid".*	**1**