Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

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Chemistry

Higher level

Paper 3

43 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 **[30 marks]**.
Maximum total = **[45 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 faulty apparatus **OR** human error.*	**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

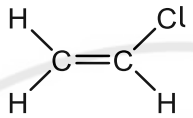
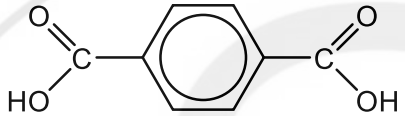
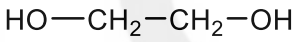
Option A — Materials

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/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**

(continued…)

(Question 3b continued)

Question			Answers	Notes	Total
3.	**b**	**iii**	*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
3.	c		<table><tr><th>Polymer</th><th>Classification</th><th>Structure of monomer(s)</th></tr><tr><td>PVC</td><td>addition</td><td>  </td></tr><tr><td>PET</td><td>condensation</td><td>  ***AND***  </td></tr></table> *PVC:* addition ***AND*** *PET:* condensation ✓ structure of PVC monomer ✓ structure of PET monomers ✓	*Accept full **OR** condensed structural formulas.*	**3**

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 two of:* have higher critical temperatures/T_c **«**than Type 1**»** ***OR*** can act at higher temperatures ✓ have higher critical magnetic fields/B_c **«**than Type 1**»** ✓ less time needed to cool to operating temperature ✓ less energy required to cool down/maintain low temperature ✓		**2 max**
4.	b	ii	*Any three of:* passing electrons **«**slightly**»** deform lattice/displace positive ions/cations ✓ electrons couple/form Cooper pairs/condense with other electrons ✓ energy propagates along the lattice in wave-like manner/as phonons ✓ Cooper pair/electron condensate/pair of electrons moves through lattice freely ***OR*** phonons are **«**perfectly**»** elastic/cause no energy loss ✓		**3 max**

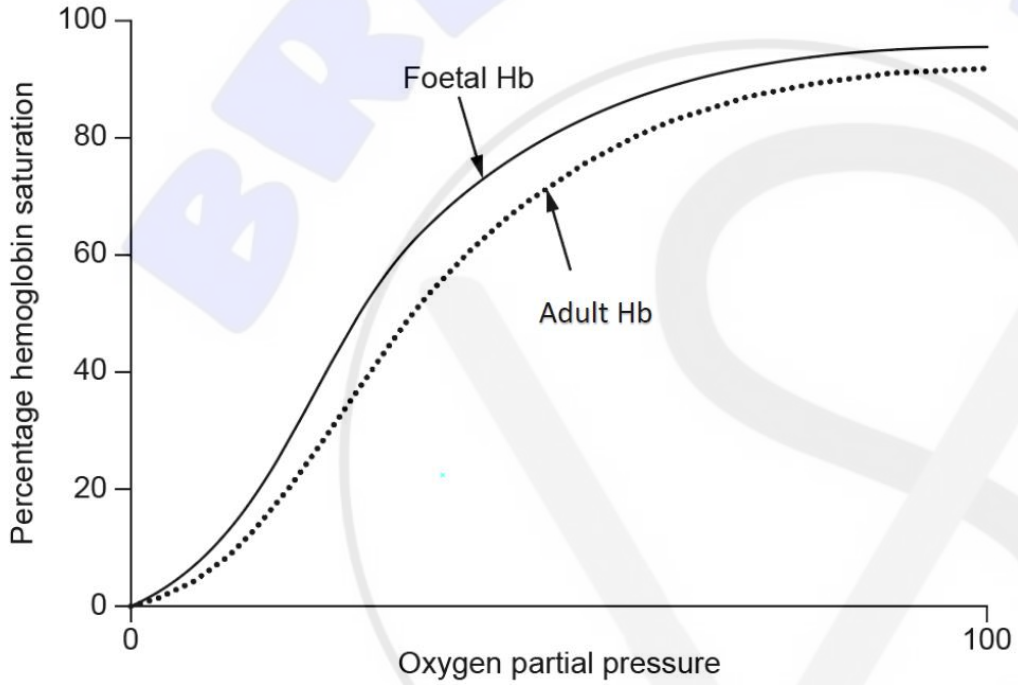
Question			Answers	Notes	Total
4.	c	i	*Any one of:* ductility ✓ strength/resistance to deformation ✓ malleability ✓ hardness ✓ resistance to corrosion/chemical resistance ✓ range of working temperatures ✓ density ✓	*Do **not** accept "conductivity".*	**1 max**
4.	c	ii	«$Q = I \times t = 3.00 \times 10.0 \times 3600 =$»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.	c	iii	argon/Ar/helium/He ✓	*Accept any identified noble/inert gas.* *Accept name **OR** formula.* *Do **not** accept "nitrogen/N_2".*	**1**

Question			Answers	Notes	Total
4.	d		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.	e		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**

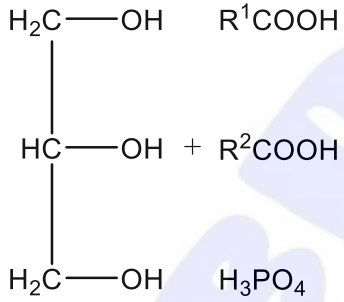
Question			Answers	Notes	Total
5.	a		$[PO_4^{3-}] = \sqrt{\frac{K_{sp}}{[Mg^{2+}]^3}}$ ✓ «$[PO_4^{3-}]$ = « $\sqrt{\frac{1.04 \times 10^{-24}}{0.0100^3}}$ =» 1.02×10^{-9} «mol dm^{-3}» ✓	*Accept "$K_{sp} = [Mg^{2+}]^3[PO_4^{3-}]^{2}$" for M1.* *Award **[2]** for correct final answer.*	**2**
5.	b		*Any two of:* precipitation occurs with a base/carbonate/CO_3^{2-}/hydroxide/OH^- ✓ $[OH^-]$ is high enough to cause metal hydroxide precipitation at that pH ✓ these ions are slightly acidic/more soluble in acidic conditions ✓ only small amounts of carbonate/hydroxides/anion needed at that pH ✓ solubility products of the hydroxides are very small ✓	*Do **not** accept "hydroxyl" for "hydroxide".*	**2 max**

Option B — Biochemistry

Question			Answers	Notes	Total
6.	**a**	**i**	0.70 ✓	*Accept any value within the range "0.67–0.73".*	**1**
6.	**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**
6.	**b**		hydrogen/H bonding **«**between amido hydrogen and carboxyl oxygen atoms**»** ✓		**1**

Question			Answers	Notes	Total
6.	c	i	 both curves sigmoidal shape ***AND*** starting at zero ✓ foetal hemoglobin showing greater affinity/steeper/higher gradient ✓	*Do **not** penalise if convergence is not approached for M1.* *Both curves must be labelled to score M2.*	**2**

Question			Answers	Notes	Total
6.	**c**	**ii**	*Any two of:* contains two gamma/γ units **«**instead of two beta/β units found in adults**»** ***OR*** differs in amino acid sequence **«**from the two beta//β units found in adults**»** ✓ less sensitive to inhibitors/2,3-BPG/DPG ✓ receives O_2 from **«**partly deoxygenated**»** blood so can work at low pO_2 ✓ low pCO_2 in foetal blood increases affinity for O_2 ✓ hemoglobin concentration in foetal blood greater than in the mother ✓		**2 max**

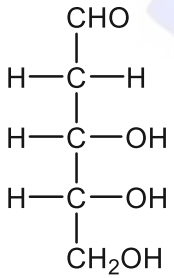
Question			Answers	Notes	Total
7.	a		 glycerol ✓ both fatty acids ***AND*** phosphoric acid ✓	*Accept either names **OR** structures.* *Accept "long chain carboxylic acid" for "fatty acid".* *Penalise once only if an incorrect name is given for a correct structure or vice-versa.*	**2**
7.	b	i	***A**:* 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 7b continued)

Question			Answers	Notes	Total
7.	**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**

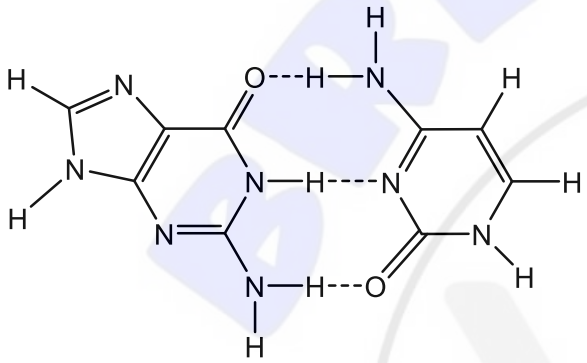
Question			Answers	Notes	Total
7.	c		*Energy storage:* not water-soluble/no hydrogen/H bonding ***OR*** less oxidized/more reduced ***OR*** high energy stored in bonds ***OR*** high «negative» enthalpy of combustion/oxidation ✓ *Electrical insulator:* no delocalized electrons/conjugation ✓	*Accept "potential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

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>8.</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>8.</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>
</table>

(continued…)

(Question 8b continued)

Question			Answers	Notes	Total
8.	**b**	**ii**	 Guanine Cytosine cytosine drawn ✓ appropriate representation of three hydrogen bonds ***AND*** between correct atoms ✓	*Structure of cytosine must be given for M1.* *Ignore missing hydrogens on carbon atoms in cytosine.* *Dashed lines (horizontal or vertical)* ***OR*** *dots can be used to represent hydrogen bonds.* *Only award M2 if M1 correct.*	**2**

Question			Answers	Notes	Total
8.	c		*Any three of:* *cis*-retinal binds to **«**the protein**»** opsin ***OR*** *cis*-retinal **«**binds to opsin and**»** forms rhodopsin ✓ opsin extends conjugation in retinal ***OR*** conjugation in rhodopsin is larger/more extended/involves more atoms than that in retinal ***OR*** rhodopsin allows absorption of visible/blue/green light ✓ when visible light is absorbed *cis*-retinal changes to *trans*-retinal ✓ change **«**to *trans*-retinal**»** triggers an electrical/nerve signal ✓ *trans*-retinal detaches from opsin ***AND*** is converted back to *cis*-retinal ***OR*** *trans*-retinal is converted back to *cis*-retinal through enzyme activity ✓		**3 max**

Question			Answers	Notes	Total
9.	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**
9.	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**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>10.</td><td>a</td><td></td><td>non-competitive «inhibition» ✓</td><td></td><td>1</td></tr>
<tr><td>10.</td><td>b</td><td>i</td><td><table><tr><th></th><th>V_{max}</th><th>K_m</th></tr><tr><td>Absence of the inhibitor</td><td>4.4</td><td>1.7</td></tr><tr><td>Presence of the inhibitor</td><td>3.0</td><td>1.7</td></tr></table>✓✓✓</td><td>Award [3] for four values correct.
Award [2] for three values correct.
Award [1] for two values correct.
Ignore units.
Accept ±0.1 for K_m and V_{max}.
No ECF applied.</td><td>3</td></tr>
<tr><td>10.</td><td>b</td><td>ii</td><td>K_m is an inverse measure of affinity of substrate for enzyme
OR
higher K_m indicates higher substrate concentration is needed for enzyme saturation
OR
low value of K_m means reaction is fast at low substrate concentration ✓</td><td>Idea of “inverse relationship” must be conveyed.</td><td>1</td></tr>
</table>

Option C — Energy

Question			Answers	Notes	Total
11.	**a**		**«**21 200 kJ dm^{-3} × 5.00 dm^3 =**»** 106000/1.06 × 10^5 **«**kJ**»** ✓		**1**
11.	**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
11.	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" for 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/rating" for disadvantage.*	

Question			Answers	Notes	Total
11.	**d**		*Any one of:* 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 11c.*	**1 max**
11.	**e**	**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**

Question			Answers	Notes	Total
11.	e	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**
11.	e	iii	any value or range within 2850–3090 «cm^{-1}» ✓		**1**
11.	e	iv	**«**rate of effusion of $\frac{CH_4}{CO_2} = \sqrt{\frac{44.01}{16.05}}$ **»** 1.656 ✓		**1**

Question			Answers	Notes	Total
12.	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**
12.	b		***Alternative 1*** «$\frac{2.23\times10^{10}\text{ year}}{4.46\times10^{9}\text{ year}}$ = » 5.00 «half-lives» ✓ «$m = 0.639\text{ kg} \times (0.5)^5$ = » 0.0200 «kg» ✓ ***Alternative 2*** «$\lambda = \frac{\ln 2}{4.46\times10^{9}\text{ year}}$ = » 1.554×10^{-10} «year^{-1}» ✓ «$m = 0.639\text{ kg} \times e^{-1.554\times10^{-10}\,year^{-1}\times2.23\times10^{10}\,\text{year}}$ = » 0.0200 «kg» ✓	*Award **[2]** for correct final answer.*	**2**

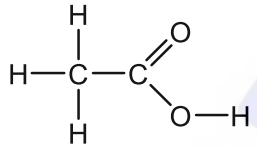
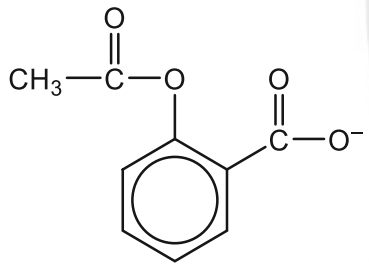
Question			Answers	Notes	Total
12.	**c**		*Any one of:* **«**genetic**»** mutations ✓ **«**could cause**»** cancer ✓ cells **«**in body**»** altered ✓ cells **«**in body**»** cannot function ✓ damaged DNA/proteins/enzymes/organs/tissue ✓ **«**radiation**»** burns ✓ hair loss ✓ damage in foetuses ✓ damages/weakens immune system ✓	*Accept specific named types of cancer.*	**1 max**
12.	**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**
12.	**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**

Question			Answers	Notes	Total
12.	**f**		238.050786 **«**amu**»** × 1.66 × 10^{-27} **«**kg amu^{-1}**»** ***OR*** 3.95 × 10^{-25} **«**kg**»** ✓ (92 × 1.672622 × 10^{-27}) + (146 × 1.674927 × 10^{-27}) − 3.95 × 10^{-25} ***OR*** 3.42 × 10^{-27}/3 × 10^{-27} **«**kg**»** ✓ **«***E* = mc^2 = 3.42 × 10^{-27} × (3.00 × 10^8)^2 =**»** 3.08 × 10^{-10} **«**J**»** ✓	*Accept answers in the range "2.7 × 10^{-10}–3.1 × 10^{-10} **«**J**»".* *Award **[3]** for correct final answer.*	**3**

Question			Answers	Notes	Total
13.	a		$Mg(s) + Ni^{2+}(aq) \rightarrow Mg^{2+}(aq) + Ni(s)$ ✓	*Accept a balanced molecular equation such as "Mg + $NiSO_4$ → $MgSO_4$ + Ni".*	1
13.	b		$E^{\ominus}$ = « 2.37 − 0.26 = » (+)2.11 «V» ✓ «$Q = \left(\frac{0.0100}{0.800}\right)$ =» 0.0125 ***AND*** «n =» 2 ✓ «$E = E^{\ominus} - \left(\frac{RT}{nF}\right) \ln Q = 2.11 - \left(\frac{8.31 \times 298}{2 \times 96\,500}\right) \ln 0.0125$ =» (+)2.17 «V» ✓	*Award **[3]** for correct final answer.*	3
13.	c		cell potential/E increases ***AND*** increasing temperature favours forward reaction ***OR*** cell potential/E increases ***AND*** ΔG becomes more negative ***OR*** cell potential/E increases ***AND*** $RT/nF \ln Q$ becomes more negative ✓	*Accept any correct mathematical explanation using the Nernst equation.*	1

Question			Answers	Notes	Total
14.	**a**		*p-type:* **«**small amount of**»** B/Al/Ga/In/Tl/Group 13 element produces holes ✓ *n-type:* **«**small amount of**»** Sb/P/As/Bi/Group 15 element adds extra electrons ✓	*Award **[1 max]** for correct element type for p **AND** n **OR** p-type: "produces holes" **AND** n-type: adds extra electrons".*	**2**
14.	**b**		electrons and holes flow in opposite directions ***OR*** electrons can flow into holes ***OR*** gap between valence and conduction bands becomes smaller ✓		**1**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
15.	**a**		 ***OR*** CH_3COOH ✓	*Accept full **OR** condensed structural formula.*	**1**
15.	**b**		to avoid dissolving the crystals/aspirin ✓	*Accept "to avoid loss of product" **OR** "aspirin is less soluble in cold water".*	**1**
15.	**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**
15.	**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**

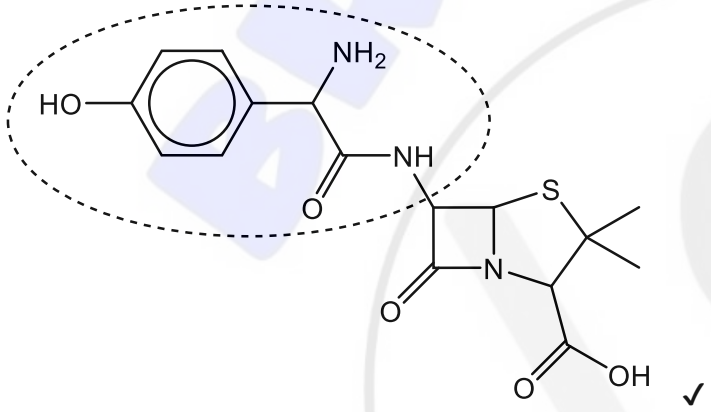
Question			Answers	Notes	Total
15.	**e**		salicylic acid contains absorption in the range 3200–3600 **«**cm^{-1}**»** ✓ due to phenol/hydroxyl/OH group not present in aspirin ✓	*Award **[2]** for "additional OH **«**stretch**»** in IR for salicylic acid at higher wavenumber than corresponding OH **«**stretch**»** in aspirin" **OR** "aspirin has two absorption bands/one stronger absorption band in 1700–1750 **«**cm^{-1}**»** while salicylic acid has one/weaker absorption band in that region".* *Award **[1 max]** for "fingerprint regions will be different for both".*	**2**

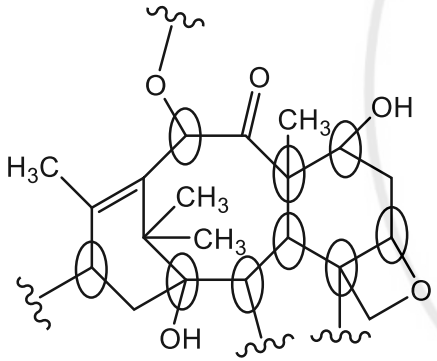
Question			Answers	Notes	Total
16.			same reactant mole ratio **«**in both equations**»** ***OR*** $Mg(OH)_2(s) + 2HCl(aq) \text{ «}\rightarrow MgCl_2(aq) + 2H_2O(l)\text{ »}$ ***AND*** $CaCO_3(s) + 2HCl(aq) \text{ «}\rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)\text{»}$ ✓ $n_{Mg(OH)_2} = \text{«}\frac{0.200}{58.32} = \text{»} 3.43 \times 10^{-3}$ **«**mol**»** ***AND*** $n_{CaCO_3} = \text{«}\frac{0.220}{100.09} = \text{»} 2.20 \times 10^{-3}$ **«**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
17.	a		gamma/γ ✓		1
17.	b		*Any three of:* «easily» detected/traced ***OR*** «gamma-radiation of approximately» same frequency as X-rays «so can be detected using existing X-ray equipment» ✓ short/intermediate half-life «hence does not remain in body for long time» ✓ weak ionizing radiation «less harmful» ***OR*** low amount of radiation produced «so less harmful» ***OR*** energy of photons is low ✓ form «variety of» compounds that are absorbed by «different» organs ***OR*** «chemically» binds to many biologically active compounds ✓ excreted quickly «from body» ✓		3 max
17.	c		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

Question			Answers	Notes	Total
17.	d		*Alternative 1:* «$N = N_0\,(0.5)^{\frac{t}{t_{1/2}}}$ =» $1.00 \times 10^{-11} \times (0.5)^{\frac{48.0}{6.03}}$ ✓ «N =» 4.02×10^{-14} «mol» ✓ *Alternative 2:* «$\lambda = \frac{\ln 2}{6.03}$ =» 0.115 «hr^{-1}» ✓ «$N = N_0\,e^{-\lambda t} = 1.00 \times 10^{-11} \times e^{-0.115 \times 48}$ =» 4.01×10^{-14} «mol» ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
18.	a	i	«$\chi_{ethanal} = \frac{0.100}{0.100 + 0.100 + 0.200}$ =» 0.250 ✓	*Accept "25%".*	1
18.	a	ii	«$p_{ethanal} = 0.250 \times 101$ =» 25.3 «kPa» ✓		1
18.	b		*Any two of:* continuous evaporation and condensation ***OR*** increased surface area in column helps condensation ✓ temperature decreases up the fractionating column ✓ liquids condense at different heights ***OR*** liquid of lowest boiling point collected first ***OR*** liquid with weakest intermolecular forces collected first ***OR*** most volatile component collected first ***OR*** fractions/liquids collected in order of boiling point/volatility ✓	*Accept "glass «beads» aid condensation «in fractionating column»".* *Accept "liquids collected in order of molar mass".*	2 max

Question			Answers	Notes	Total
19.	a		«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
19.	b	i	 ✓	*Accept a circle that does not surround the amido group.* *Do **not** accept a circle that only surrounds the phenol group.*	1
19.	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 penicillin" for M2.* *Award **[1 max]** for "increased efficiency" **OR** "increased stability in GIT".* *Do **not** accept "bacteria develop tolerance".*	2

Question			Answers	Notes	Total
19.	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 <u>hydrogen/H bonding</u> «due to more hydroxyl groups leads to greater solubility» ✓		**2**
19.	c	ii	opium poppy/plants/seeds ✓	*Accept "poppy" **OR** "opioid".*	**1**
19.	d		 any two chiral carbons identified ✓		**1**