Diploma Programme
Programme du diplôme
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Markscheme

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Chemistry

Higher level

Paper 3

25 pages

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

Section A

Question			Answers	Notes	Total
1.	a		«$\frac{0.5}{25.0} \times 100$» = 2 «%» ✓		1
1.	b		pipette/pipet «rather than a measuring cylinder» ✓	*Accept using a burette/buret.* *Accept using a volumetric/measuring flask.* *Do not accept "use of a more precise measuring cylinder".*	1
2.	a		more «moles/amount» of acid have been added/reacted ***OR*** more of the limiting reagent is present ***OR*** more «of the exothermic» reaction has occurred ✓		1
2.	b		no more reaction/same energy released ***AND*** cold/colder/cooler liquid added ***OR*** no more reaction/same energy released ***AND*** greater total volume of liquid ✓	*Accept "no more reaction/same energy released **AND** greater heat loss «to the surroundings in mixture D»".*	1
3.			volume «found by extrapolation of the two best fit lines» required to give the highest temperature ***OR*** extrapolate «two best fit» lines to the point where they meet ✓	*Accept "where lines through the points meet".* *Accept "at maximum temperature".* *Accept "at 35 cm^3 of HCl".*	1

Question			Answers	Notes	Total
4.			graph would peak/maximum at 17.5 cm^3 ***OR*** half/smaller volume of acid **«**to reach equivalence» ✓ sulfuric acid is dibasic/diprotic ✓ higher temperature would be reached ✓	*Accept "graph would peak at a smaller volume" for M1.* *Accept "gradient/slope **«**of graph**»** is greater/steeper" for M1.* *Accept "1 mol sulfuric acid neutralizes 2 mol of sodium hydroxide" for M2.*	**2 max**

Question			Answers	Notes	Total
5.	**a**		heat change/evolved can be calculated from the **«**maximum**»** temperature increase and the mass of solution ***OR*** $q = mc\Delta T$ ✓ heat **«**evolved**»** gives the number of moles **«**of both acid and alkali present when neutralisation occurs**»** ***OR*** $n = \frac{q}{\Delta H_{neut}}$ ✓ volume **«**of acid and the volume of alkali required to just neutralise each other**»** can be used to calculate the concentration**«**s of both**»** ***OR*** $[NaOH] = \frac{n}{V}$ ✓		**2 max**
5.	**b**		smaller temperature increase/ΔT ***OR*** heat released would **«**appear to» be less✓ amount of substance/n **«**calculated is **»** smaller ✓		**2**

5.	**c**		using **«**expanded**»** polystyrene cup ***OR*** insulating beaker ***OR*** putting a lid on beaker ✓	*Accept any other reasonable suggestion.* *Do not accept "calorimeter" by itself.*	**1**
5.	**d**		**«**specific**»** heat capacity of the beaker/container/thermometer is ignored ***OR*** density of the solutions is assumed as 1.00 g cm^{-3}/same as water ***OR*** specific heat capacity of the solutions is assumed as 4.18 J g^{-1} K^{-1}/same as water ✓	*Accept "reaction goes to completion".* *Accept "reaction is conducted under standard conditions".* *Accept "no evaporation occurs".* *Accept any other relevant valid assumption.* *Do **not** accept "heat is not released from other reactions".*	**1**
5.	**e**		allows simple theories to be applied to real life situations ***OR*** enables us to start to understand complex situations ***OR*** gives answers that are accurate to the required order of magnitude ***OR*** simplifies the calculations involved ✓	*Accept "errors do not have a major impact on the results".* *Do **not** accept "to simplify the situation" without further detail.*	**1**
5.	**f**		temperature rise would be too small **«**to be accurately measured**»** ✓	*Accept "heat released would be too small «to be accurately measured»".*	**1**

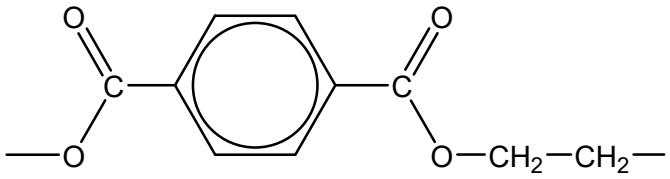
Section B

Option A — Materials

Question			Answers	Notes	Total
6.	**a**		polar covalent ✓ average electronegativity **«**$= \frac{1}{2}(3.0 + 2.0)$**»** $= 2.5$ ***AND*** electronegativity difference **«**$= 3.0 - 2.0$**»** $= 1.0$ ✓		**2**
6.	**b**		ionic bonding ***OR*** electrostatic forces between ions ✓ **«**slight**»** movement brings ions of same charge adjacent to each other **«**causing the crystal to break**»** ***OR*** **«**slight**»** movement results in repulsion between layers **«**causing the crystal to break**»** ✓		**2**

7.	**a**		too high/higher than carbon in the reactivity series ***OR*** carbon/C is a weaker reducing agent than lanthanum/La ✓	*Accept "lanthanum is more reactive than carbon".* *Accept "lanthanum is a weaker oxidizing agent than carbon".* *Accept converse arguments.*	**1**
7.	**b**		amount of La **«**$= \frac{1000\,\text{g}}{138.91\,\text{g mol}^{-1}}$**»** $= 7.20$ **«**mol**»** ✓ Q **«**$= 7.20\ \text{mol} \times 3 \times 96\,500\ \text{C mol}^{-1}$**»** $= 2.08 \times 10^6$ **«**C**»** ✓ I **«**$= \frac{2.08 \times 10^6\,\text{C}}{60 \times 60\,\text{s}}$**»** $= 579$ **«**A**»** ✓	*Award [3] for "578 «A»" (from premature rounding) or "579 «A»".*	**3**

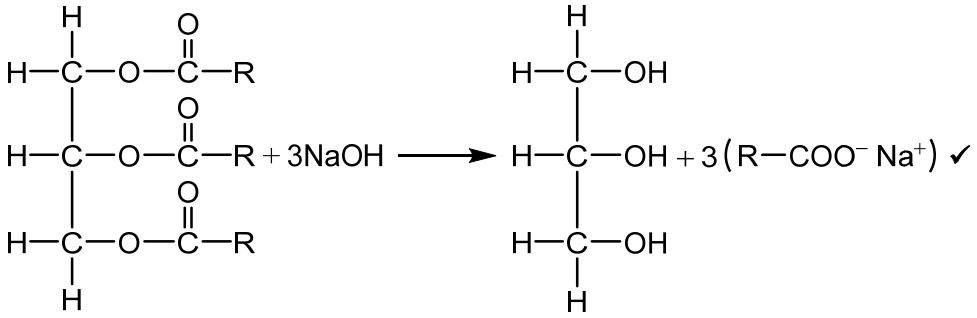
Question			Answers	Notes	Total
8.	a		twelve/12 ✓		1
8.	b		«moving» electron attracts «nearby» positive charges/ions/cations ✓ creates «local» regions of increased positive charge ✓ positive charge/field attracts second electron «with opposite spin» ✓ two electrons form a Cooper pair ✓ «all» Cooper pairs «in sample» interact/form «electron» condensate ✓ «electron» condensate/Cooper pairs move/flow «through sample» freely/without resistance ✓		3 max
8.	c		reduces the band gap to zero ***OR*** «at high temperatures» thermal motion disrupts the formation of Cooper pairs ✓		1

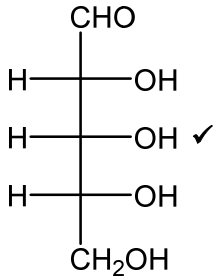
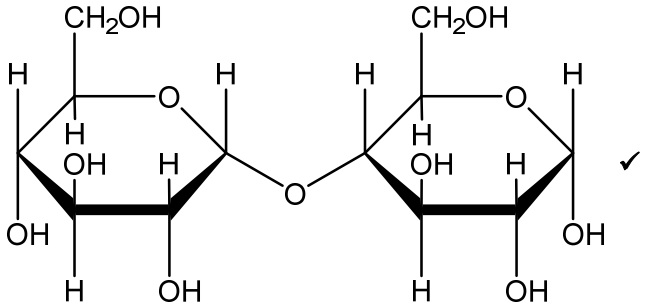
9.	a		*Repeating unit:*  ✓ *Other product:* water/H_2O ✓	*Continuation bonds necessary for the mark.* *Accept alternative repeating unit with O at other end.* *Do **not** penalize square brackets or n.*	2
9.	b		condensation ✓	*Accept polyester or thermoplastic.*	1
9.	c		combine with reactants to form «a temporary» activated complex/intermediate ***OR*** consumed in one reaction/step ***AND*** regenerated in a later reaction/step ✓		1
9.	d		can modify/improve the catalyst/reaction «by making logical predictions» ***OR*** science relies on models to understand physical reality ✓	*Accept other reasonable, relevant answers.* *Accept "to predict/select the ideal catalyst for a reaction".*	1

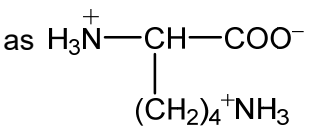
Question			Answers	Notes	Total
10.	a		electrons ***AND*** positive ions **«**in gaseous state**»** ✓ high frequency/alternating current passed through argon ***OR*** **«**oscillating**»** electromagnetic/magnetic field ***OR*** high frequency radiowaves ✓	*Accept "gas" instead of "argon".*	**2**
10.	b		$K_{sp} = [Sb^{3+}]^2.[S^{2-}]^3$ ✓ $[Sb^{3+}]^2.\ (10^{-14})^3 = 1.6 \times 10^{-93}$ ✓ $[Sb^{3+}]$ **«**$= \sqrt{1.6 \times 10^{-51}}$ **»** $= 4.0 \times 10^{-26}$ **«**mol dm^{-3}**»** ✓	*Award [3] for correct final answer.*	**3**
10.	c		EDTA/ethylenediaminetetraacetic acid ***OR*** $H_2N–CH_2–CH_2–HN_2$/ethane-1,2-diamine ✓	*Accept "$EDTA^{4-}$".* *Accept other chelating agents.*	**1**

Question			Answers	Notes	Total
11.	**a**		*A RIC:* 1 ***AND*** *B RIC:* 4 ✓ ***ALTERNATIVE 1:*** **«**only**»** PETE contains carbonyl/C=O/ester/COO groups ✓ carbonyl groups absorb at 1700–1750 **«**cm^{-1} **»** ✓ ***ALTERNATIVE 2:*** LDPE contains more C–H bonds **«**than PETE**»** ✓ C–H bonds absorb at 2850–3090 **«**cm^{-1} **»** ✓	*For either, accept specific frequencies in these ranges (eg 1735 «cm^{-1} » or 2900 «cm^{-1}»).*	**3**
11.	**b**	**i**	HDPE less branched ***OR*** LDPE more branched ✓	*Accept "no branching in HDPE **AND** branching in LDPE".*	**1**
11.	**b**	**ii**	HDPE **«**polymer**»** chains/molecules can pack together more closely **«**than LDPE chains**»** ***OR*** HDPE **«**polymer**»** chains/molecules have a higher contact surface area **«**than LDPE chains**»** ✓ stronger intermolecular/dispersion/London/van der Waals' forces in HDPE ***AND*** higher melting point ✓	*Accept converse arguments.*	**2**

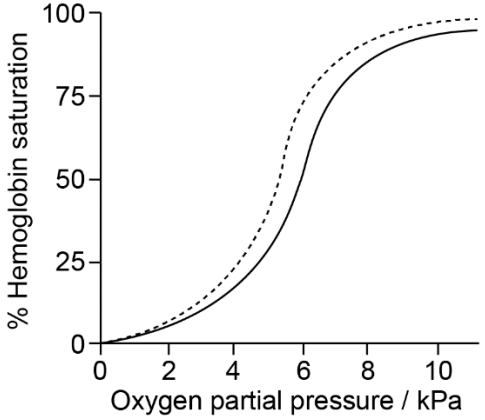
Option B — Biochemistry

Question			Answers	Notes	Total
12.	**a**	**i**	«water/aqueous solubility depends on forming many» H-bonds with water ✓ raffinose has many hydroxyl/O–H/oxygen atoms/O «and forms many H-bonds» ***AND*** linoleic acid has few/one hydroxyl/O–H/oxygen atom/O/carboxyl group/ COOH/is largely non-polar «and cannot form many H-bonds» ✓	*Accept statement which implies comparison.*	**2**
12.	**a**	**ii**	«base» hydrolysis/saponification ***OR*** «produces glycerol and» soap/salt of the «fatty» acid ✓  «products are» water soluble «and drain away» ✓	*Accept condensed formulas.* *Accept non-balanced equation.* *Accept "RCOONa".*	**2 max**
12.	**b**		linoleic acid/$C_{18}H_{32}O_2$ combustion/oxidation more exothermic «per mol» ✓ linoleic acid/$C_{18}H_{32}O_2$ has lower proportion/number of O atoms ***OR*** linoleic acid/$C_{18}H_{32}O_2$ is less oxidized ✓	*Accept converse arguments.*	**2**

Question			Answers	Notes	Total
13.	a	i	 ✓	*All OH groups must be on the same side.* *Accept structures with chiral carbon atoms shown as C or C* instead of crosses.*	1
13.	a	ii	 ✓	*Accept –O– in a straight line provided both Hs are above the plane.*	1
13.	b		«allow» 3-D perspective of structures «of cyclic monosaccharide molecules» ***OR*** «show» *cis*/same side arrangement of «attached» groups ***OR*** «show» *trans*/opposite side arrangement of «attached» groups ***OR*** «make» carbon and hydrogen implicit ✓		1
13.	c	i	abundant/renewable/allows use of «local» vegetation ***OR*** less use of fossil fuel/oil based plastics ***OR*** air permeable/better breathing of products ***OR*** «can be» mixed/blended with synthetic polymers ✓	*Do **not** accept answers related to biodegradable examples.* *Ignore any reference to cost.* *Accept "carbon neutral/do not contribute to global warming".* *Accept "require less energy to produce".* *Accept "do not produce toxic products".*	1
13.	c	ii	$HO–CH(CH_3)–COOH/CH_3CH(OH)COOH$ ✓	*Do **not** accept $C_3H_6O_3$.* *Do **not** accept $OH\text{-}CH(CH_3)\text{-}COOH$.*	1

Question			Answers	Notes	Total
14.	a		catabolism/catabolic ✓		1
14.	b	i	alanine ✓	*Do **not** accept Ala.*	1
14.	b	ii	Lys/lysine ✓ pH «buffer» < pI «*Lys*» ***OR*** buffer more acidic than Lys «at isoelectric point» ***OR*** «Lys» exists as  ***OR*** «Lys» charged positively/has +1/1+ «overall» charge «and moves to negative electrode» ✓	*Do **not** apply ECF from M1.* *Accept converse arguments.* *Do **not** accept just "has H_3N^+ group" for M2 (as H_3N^+ is also present in zwitterion).* *Do not penalize if –COOH is given in the structure of lysine at pH 6 instead of $–COO^–$.*	2
14.	c		highest <u>frequency</u> of <u>successful</u> collisions between active site and substrate ***OR*** highest <u>frequency</u> of collisions between active site and substrate with sufficient energy/$E \geq E_a$ ***AND*** correct orientation/conformation ***OR*** optimal shape/conformation of the active site «that matches the substrate» ***OR*** best ability of the active site to bind «to the substrate» ✓	*Accept "number of collisions per unit time" for "frequency".* *Do **not** accept "all active sites are occupied".*	1
14.	d		ascorbic acid/vitamin C ✓		1
14.	e		react/bind/chelate with enzyme ***OR*** disrupt ionic salt bridges ***OR*** affect shape of tertiary/quaternary structures ***OR*** precipitate enzymes ***OR*** break/disrupt disulfide bridges/bonds ✓	*Do **not** accept "changes shape of active site" by itself.*	1

Question			Answers	Notes	Total
15.	**a**		**«**pH range**»** 8.6–10.6 ✓	*Accept any value between 8.2 and 11.0.*	**1**
15.	**b**		**«**K_m =**»** 0.67 **«**mmol dm^{-3}**»** ✓	*Do not penalize if a graph is drawn to determine the value.*	**1**
15.	**c**		does not compete for active site ***OR*** binds to allosteric site/away from **«**enzyme**»** active site ***OR*** alters shape of enzyme ✓ reduces rate/V_{max} ✓		**2**
15.	**d**		**«**% cytosine + % guanine = 100 % − 17 % − 17 % = 66 %**»** Cytosine: 33 **«**%**»** ***AND*** Guanine: 33 **«**%**»** ✓ Thymine: 17 **«**%**»** ✓		**2**

Question			Answers	Notes	Total
16.	**a**		binding of O_2 **«**to one active site**»** affects shape of Hb/other active sites ***OR*** binding of one O_2 **«**molecule**»** affects binding of other O_2 **«**molecules**»** ✓ increasing affinity of Hb to O_2 ***OR*** enhanced binding of **«**further**»** O_2 **«**molecules**»** ***OR*** cooperative binding ✓		**2**
16.	**b**	**i**	 sketching right shift of curve on graph ✓		**1**
16.	**b**	**ii**	decreases **«**oxygen saturation**»** ✓	*Accept "hemoglobin binds to O_2 with less affinity".*	**1**

17.			11-*trans* retinal no longer fits into the rhodopsin/protein ***OR*** 11-*trans* retinal is ejected from the rhodopsin/protein ✓ leads to conformational change in rhodopsin/protein **«**to opsin generating signals**»** ✓		**2**

Option C — Energy

Question			Answers	Notes	Total
18.	**a**		presence of dark/absorption lines corresponding to those found for carbon ***OR*** missing wavelengths/frequencies corresponding to carbon's spectrum ✓	*Accept "presence of characteristic dark lines".* *Do **not** accept responses in terms of emission spectra.*	**1**
18.	**b**	**i**	$^{8}_{4}Be$ ✓		**1**
18.	**b**	**ii**	loss in mass = **«**8.005305 amu + 4.002603 amu − 12.000000 amu =**»** 0.007908 **«**amu**»** ✓ = **«**0.007908 amu × 1.66×10^{-27} kg amu^{-1} =**»** 1.313×10^{-29} **«**kg**»** ✓ E = **«**$mc^2 = 1.313 \times 10^{-29}$ kg × $(3.00 \times 10^{8}$ m $s^{-1})^2$ =**»** 1.18×10^{-12} **«**J**»** ✓	*Award [3] for correct final answer.*	**3**
18.	**c**		fuel more abundant/cheaper ✓ no **«**long half-life**»** radioisotopes/radioactive waste ✓ shipment of radioactive fuels not required ✓ plutonium/nuclear weapons cannot be produced from products ✓ nuclear disasters less likely **«**as no critical mass of fuel required**»** ✓ higher specific energy/energy per g/kg/unit mass than fission ✓	*Do **not** accept simply "fusion produces more energy than fission".*	**2 max**

19.	**a**		delocalized bonding/conjugated bonds ✓ contain metal atom/ion coordinated to **«**organic**»** ligand(s) ✓ involve bonds from nitrogen to the central metal ion ✓		**2 max**
19.	**b**		$I_3^- + 2e^- \rightarrow 3I^-$ ✓	*Accept $I_2 + 2\ e^- \rightarrow 2I^-$.*	**1**

Question			Answers	Notes	Total
20.	**a**		methanol ***OR*** ethanol ✓ strong acid ***OR*** strong base ✓	*Accept alcohol.* *Accept any specific strong acid or strong base other than HNO_3/nitric acid.*	**2**
20.	**b**		$CH_3(CH_2)_{16}COOCH_3$ / $CH_3OCO(CH_2)_{16}CH_3$ ***OR*** $CH_3(CH_2)_{16}COOC_2H_5$ / $C_2H_5OCO(CH_2)_{16}CH_3$ ✓	*Product **must** correspond to alcohol chosen in (a), but award mark for either structure if neither given for (a).*	**1**
20.	**c**		Specific energy **«**$= \frac{12000\,kJmol^{-1}}{299\,gmol^{-1}}$**»** $= 40.1$ **«**kJ g^{-1}**»** ✓ Energy density **«**$= 40.1$ kJ $g^{-1} \times 0.850$ g cm^{-3}**»** $= 34.1$ **«**kJ cm^{-3}**»** ✓	*Award [1] if both are in terms of a unit other than kJ (such as J or MJ).*	**2**
21.	**a**		heat/react with **«**oxygen and**»** water/steam ✓ $C + H_2O \rightarrow CO + H_2$ ***OR*** $3C + O_2 + H_2O \rightarrow H_2 + 3CO$ ***OR*** $2C + O_2 \rightarrow 2CO$ ***AND*** $C + H_2O \rightarrow H_2 + CO$ ***OR*** $C + O_2 \rightarrow CO_2$ ***AND*** $C + CO_2 \rightarrow 2CO$ ***AND*** $C + H_2O \rightarrow H_2 + CO$ ✓	*M1 requires concept of heat.*	**2**
21.	**b**		**«**Fischer-Tropsch**»** catalytic reduction of carbon monoxide with hydrogen ***OR*** $(2n+1)\,H_2 + n\,CO \rightarrow C_nH_{(2n+2)} + n\,H_2O$ ***OR*** reduction of carbon monoxide to methanol and catalytic dehydration ***OR*** $2H_2 + CO \rightarrow CH_3OH$ ***AND*** $n\,CH_3OH \rightarrow C_nH_{2n} + n\,H_2O$ ✓	*If equation is given for a specific alkane or alkene, it must be a liquid (n>4).*	**1**

Question			Answers	Notes	Total
22.	**a**		*Anode:* $CH_3OH\ (aq) + H_2O\ (l) \rightarrow CO_2\ (aq) + 6H^+\ (aq) + 6e^-$ ✓ *Cathode*: $O_2\ (aq) + 4H^+\ (aq) + 4e^- \rightarrow 2H_2O\ (l)$ ✓ *Overall:* $2CH_3OH\ (aq) + 3O_2\ (g) \rightarrow 2CO_2\ (aq) + 4H_2O\ (l)$ ✓	*Accept correctly balanced equations with multiples of the coefficients given here.* *Accept reversible or non-reversible arrows for all.*	**3**
22.	**b**	**i**	**«**portable**»** sources of electrical energy/electricity ***OR*** convert chemical **«**potential**»** energy to electrical energy/electricity ✓		**1**
22.	**b**	**ii**	primary cells involve irreversible reactions ***AND*** rechargeable cells involve reversible reactions ✓	*Accept "primary cells have a limited life before going 'flat' **AND** rechargeable cells can be recharged when 'flat'".*	**1**
22.	**c**		*Voltage:* chemical nature of electrodes ***OR*** electrode reactions ✓ *Current:* diffusion rate ***OR*** internal resistance/resistance of the cell ✓	*Accept temperature for either but not both.* *Accept concentration for either but not both.* *Accept pH for either but not both.* *Accept the current depends on the area/separation of the electrodes.*	**2**

Question			Answers	Notes	Total
23.	a		computers can now carry out more complex calculations ***OR*** better understanding of the interactions between the various systems involved ***OR*** clear evidence of global warming ***OR*** **«**reliable**»** global temperature data now available ***OR*** techniques have been available to monitor carbon dioxide levels ✓	*Accept "better/faster computers".* *Accept "better modelling".* *Accept "better/more reliable/consistent data".* *Accept "better measuring techniques".* *Accept other scientifically based (not politically based) reasons.* *Accept if specific relevant data is given.* *Do **not** accept "increased combustion of fossil fuels" or "increased concerns about global warming".*	**1**
23.	b		symmetric stretching will not absorb IR ***OR*** asymmetric stretching will absorb IR ✓ change in polarity/dipole **«**moment**»** required **«**to absorb IR**»** ✓		**2**
23.	c		CO_2 (aq) + H_2O (l) $\rightleftharpoons$ H^+ (aq) + HCO_3^- (aq) **«**and pH decreases**»** ***OR*** CO_2 (aq) + H_2O (l) $\rightleftharpoons$ H_2CO_3 (aq) ***AND*** H_2CO_3 (aq) $\rightleftharpoons$ H^+ (aq) + HCO_3^- (aq) **«**and pH decreases**»** ✓	*Accept reversible or non-reversible arrows for all.*	**1**
23.	d		reduce it ***AND*** absorbing/reflecting sunlight ✓	*Accept "reduce it because of global dimming".* *Accept "reduce it **AND** blocking sunlight".*	**1**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
24.	**a**		«measures» therapeutic window/margin «of a drug» ***OR*** range of doses that produce a therapeutic effect without causing toxic effects ✓	*Accept "difference between ED_{50}/minimum effective/therapeutic dose «for 50 % of population» **AND** TD_{50}/toxic dose «for 50 % of population»".* *Do **not** accept "therapeutic index".* *Do **not** accept lethal/fatal dose as this is not LD_{50}.*	**1**
24.	**b**		work directly on opioid/pain receptors «in brain» ✓ suppress pain impulses in brain/CNS ✓ resemble endorphins/enkephalins/natural chemical painkillers «produced in the brain and spinal cord» ✓	*Do **not** award mark for "resemble hormones".*	**2 max**

Question			Answers	Notes	Total
25.	a		presence of «large» benzene/arene ring ***AND*** non-polar/hydrophobic ***OR*** presence of «large» benzene/arene ring ***AND*** cannot form H-bond with water ✓ contain –COOH/carboxyl/–OH/hydroxyl «and ester group» ***AND*** polar/hydrophilic ***OR*** contain –COOH/carboxyl/–OH/hydroxyl «and ester group» ***AND*** can form H-bonds with water ✓	*Accept "phenyl" for "benzene ring".* *Accept "carboxylic acid" for "carboxyl".* *Do **not** accept "alcohol" for hydroxyl".*	**2**
25.	b		«student's» sample impure ✓ crystal lattice disrupted/not uniform «due to presence of impurities» ***OR*** fewer interparticle/intermolecular forces «due to presence of impurities» ✓	*Accept converse statements.*	**2**
25.	c		*One similarity:* peak at 2500–3000 «cm^{-1}»/ peak due to O–H/hydroxyl in carboxylic acids ***OR*** peak at 1700–1750 «cm^{-1}»/ peak due to C=O/carbonyl ***OR*** peak at 2850–3090 «cm^{-1}»/ peak due to C–H of arene ✓ *One difference:* peak at 3200–3600 «cm^{-1}» in salicylic acid/ peak due to O–H in phenol in salicylic acid ***OR*** «two» peaks at 1700–1750 «cm^{-1}» in aspirin ***AND*** one peak «in the same area» in salicylic acid ✓	*Accept peak at 1600 cm^{-1} for arene/ benzene ring – not in the data booklet.* *Accept "2500–3600 cm^{-1} «overlapping absorptions of two O–H» in salicylic acid".* *Accept "stronger/broader/split peak at 1700–1750 cm^{-1} in aspirin".*	**2**
25.	d		dissolve compounds in an organic solvent ✓ add NaOH(aq)/OH^-(aq) «to the mixture» to convert aspirin to its water soluble salt ✓ separate the two «immiscible» layers ✓ convert salt «in aqueous layer» back to aspirin by reacting with acid/H^+ ✓ «evaporate solvents and dry»	*Accept organic solvents immiscible with water such as hexane, ethyl ethanoate, butyl acetate.* *Accept any other base.* *Need explanation for mark*.	**3 max**

25.	**e**		«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/regulatory solutions.* *"catalysis" not sufficient for mark*.	**1**

Question			Answers	Notes	Total
26.	**a**		«$pH = pK_a + \log_{10}\left(\frac{[HCO_3^-]}{[CO_2]}\right) = 6.34 + \log_{10}(11.2) = 6.34 + 1.05$» = 7.39 ✓		**1**
26.	**b**		H^+ from aspirin reacts with HCO_3^- to form CO_2 and H_2O ***OR*** $H^+ (aq) + HCO_3^- (aq) \rightleftharpoons CO_2 (aq) + H_2O (l)$ ***OR*** reverse reaction favoured «to use up some of the H^+ added» ✓ pH decreases ✓	*No mark for "stating aspirin is a weak acid that dissociates partially to produce H^+" without reference to reaction with HCO_3^- or to the equation.* *Reversible arrows not required for the mark.* *Do **not** accept "small pH change when small amount of H^+ is added".*	**2**

Question			Answers	Notes	Total
27.	**a**		«drug» blocks/inhibits «viral» enzyme/neuraminidase/NA «activity» ✓ prevents virus from leaving/escaping host cells «thus cannot infect other cells» ✓		**2**
27.	**b**		***ALTERNATIVE 1:*** «using» genetically modified/GM *E. Coli*/bacteria/microorganisms ✓ *E. Coli*/bacteria biosynthesis ***OR*** *E. Coli*/bacteria «overfed by glucose» undergo fermentation ***OR*** cells of the bacteria «are broken down to» form precursor/shikimic acid ✓ ***ALTERNATIVE 2:*** use readily available cyclic ester/lactone ✓ forms «the correct stereoisomer of oseltamivir» in a shorter number of chemical steps ✓	*Do **not** accept "planting more Chinese star anise" or other plant sources of shikimic acid.*	**2**
27.	**c**		«can develop antibiotic» resistance in <u>bacteria</u>/<u>microorganisms</u> ***OR*** changes in <u>microbial</u>/<u>bacterial</u> population ✓	*Accept secondary effects, such as reduced biodiversity of aquatic/soil ecosystems, denitrification of soil (due to decline in nitrogen-fixing bacteria).* *No mark for just stating "water contamination".* *No mark for just stating "failure of aquatic/marine environment".*	**1**

Question			Answers	Notes	Total
28.	**a**		plane of polarization is rotated ✓	*Award zero if answer refers to plane-polarized light being bent.*	**1**
28.	**b**		not a racemic mixture ***OR*** two enantiomers not equimolar ***OR*** mixture contains optically active impurity ***OR*** relative proportions of enantiomers in mixture can be determined ✓		**1**

Question			Answers	Notes	Total
29.	**a**		$^{90}Y \rightarrow {}^{90}Zr + \beta^-$ ✓	*Accept β, e or e^-.* *Accept $^{90}Y \rightarrow {}^{90}Zr + \beta^- + \nu$*	**1**
29.	**b**		beta-radiation/emission ***AND*** targets tumour/cancer cells ***OR*** beta-radiation/emission ***AND*** limited damage to healthy cells/tissues ***OR*** beta-radiation/emission ***AND*** produces **«**small amount of**»** gamma-rays **«**for visualizing tumours/monitoring treatment**»** ✓		**1**
29.	**c**	**i**	$\lambda \left(= \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{0.693}{8.02 \text{ day}}\right) = 8.64 \times 10^{-2} / 0.0864$ **«**day^{-1}**»** ✓		**1**
29.	**c**	**ii**	***ALTERNATIVE 1:*** **«**N_0 = initial amount = 100 %**»** N **«**= 100 − 90**»** = 10 % at time t ✓ **«** $\ln\left(\frac{100}{10}\right) = 2.303 = 0.0864t$ **»** **«** $t = \frac{2.303}{0.0864 \text{ day}^{-1}} =$ **»** 26.7 **«**days**»** ✓ ***ALTERNATIVE 2:*** **«**$N_t = N_0(0.5)^n$ where n = number of half-lives**»** $10 = 100(0.5)^n$ ✓ **«** $\log\left(\frac{1}{10}\right) = n \times \log 0.5$ **»** **«** $-1 = n(-0.301) / n = \frac{1}{0.301}$ **»** **«** $t = \frac{1}{0.301} \times 8.02 =$ **»** 26.6 **«**days**»** ✓	*Accept 26.6 or 27 **«**days**»*** *Award [2] for correct final answer.* *Accept 26.7 or 27 **«**days**»*** *Award [2] for correct final answer.*	**2**
29.	**d**		*Anode (negative electrode):* $C_2H_5OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$ ✓ *Cathode (positive electrode):* $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ ✓		**2**