M19/4/CHEMI/HP3/ENG/TZ2/XX/M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2019

Chemistry

Higher level

Paper 3

37 pages

Section A

Question			Answers	Notes	Total
1.	a		6 ✓	*Accept "orange juice".*	1
1.	b	i	equilibrium is being established «between lead in solution and in mug» ***OR*** solution becoming saturated ***OR*** concentration of lead ions/[Pb^{2+}] in the solution has increased «over time» ***OR*** acid concentration has decreased «as reacted with lead» ***OR*** surface lead has decreased/formed a compound/forms insoluble layer on surface ***OR*** acid reacts with other metals «because it is an alloy» ✓	*Do **not** accept "concentration of cola, orange juice, etc… has decreased"* *Do **not** accept a response that only discusses mathematical or proportional relationships.*	1
1.	b	ii	no ***AND*** experiment 7/beer has lowest rate and intermediate acidity/pH ***OR*** no ***AND*** experiment 6/orange juice has fastest rate but lower acidity/higher pH than lemonade ***OR*** no ***AND*** experiment 6/orange juice has highest rate and intermediate acidity/pH ✓	*Accept no **AND** any comparison, **with experimental support**, that concludes no pattern/increase with acidity* *eg: "rate of Pb/lead dissolving generally decreases with acidity as tap water has highest rate (after orange juice) while lemonade (lower pH) has lower rate".*	1

Question			Answers	Notes	Total
1.	c	i	equilibrium shifts to the left/towards reactants ✓ lead «compounds/ions» precipitate ***OR*** concentration of lead «ions»/[Pb^{2+}] decreases ✓	*Award **[2]** for "equilibrium shifts to the left/towards reactants due to common ion effect".* *Accept "lead ions/[Pb^{2+}] removed from solution" for M2.*	**2**
1.	c	ii	«daily limit = 5.0×10^{-6} g $kg^{-1} \times 80.0$ kg =» 4.0×10^{-4} «g of lead» ✓ «volume = $\frac{4.0 \times 10^{-4}\ g}{1.5 \times 10^{-2} g\ dm^{-3}}$ =» 2.7×10^{-2}/0.027 «dm^3» ✓	*Award **[2]** for correct final answer*	**2**

Question			Answers	Notes	Total
2.	a		tangent drawn to curve at t = 20 s ✓ slope/gradient calculation ✓ 0.35 «$cm^3\ s^{-1}$» ✓	*Accept values in the range 0.32–0.42 «$cm^3\ s^{-1}$».*	3
2.	b		***ALTERNATIVE 1*** colour ✓ Br_2 /reactant is coloured «Br^- (aq) is not» ✓ ***ALTERNATIVE 2*** conductivity ✓ greater/increased concentration of ions in products ✓ ***ALTERNATIVE 3*** mass/pressure ✓ gas is evolved/produced ✓ ***ALTERNATIVE 4*** pH ✓ methanoic acid is weak ***AND*** HBr is strong ***OR*** increase in $[H^+]$ ✓	*Do **not** accept "changes in temperature" or "number of bubbles".* *Do **not** accept "mass of products is less than mass of reactants".*	2

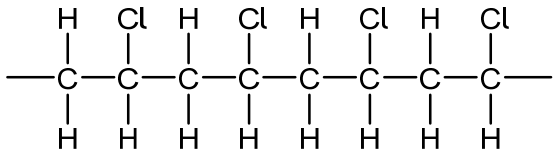
Question			Answers	Notes	Total
2.	c	i	***ALTERNATIVE 1*** gas may leak/be lost/escape ***OR*** plunger may stick/friction **«**so pressure is greater than atmospheric pressure**»** ***OR*** syringe may be tilted **«**up**»** so plunger moves less **«**with gravity acting on plunger**»** ***OR*** CO_2 dissolved in water ✓ calculated rate lower ✓ ***ALTERNATIVE 2*** syringe may be tilted **«**down**»** so plunger moves more **«**with gravity acting on plunger**»** ***OR*** syringe is held in hand so gets warmer and gas expands ✓ calculated rate higher ✓	*Calculated rate is lower or higher must be stated for M2.* *Do **not** accept "scale on syringe is inaccurate", "errors in reading syringe", or "bubbles in syringe".*	**2**
2.	c	ii	human reaction time/delay **«**starting/stopping the stopwatch**»** ✓	*Do **not** accept "inaccurate stopwatch".*	**1**

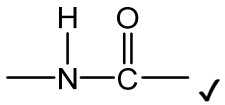
Section B

Option A — Materials

Question			Answers	Notes	Total
3.			*Shape of molecules:* linear ***OR*** rod «shaped» ✓ *Distribution:* no positional order ***AND*** «some» directional order ✓	*Accept "partly ordered".*	**2**

Question			Answers	Notes	Total
4.	a		moles of electrons «$= \frac{48\,250\ \text{C}}{96\,500\ \text{C mol}^{-1}}$» $= 0.5000$ «mol» ✓ moles of aluminium «$= \frac{0.5000\ \text{mol}}{3}$» $= 0.1667$ «mol» ✓ mass of aluminium «$= 26.98\ \text{g mol}^{-1} \times 0.1667\ \text{mol}$» $= 4.50$ «g» ✓	*Award **[3]** for correct final answer.*	**3**
4.	b		*Any two of:* larger linear calibration ✓ «accurate» detection of multiple elements/metals ✓ «accurate» detection of elements in low concentration ✓ temperature around 10 000 K atomises/ionises every material ✓		**2 max**
4.	c		*Any two of:* reactant(s) adsorb onto active sites/surface ✓ bonds weakened/broken/stretched «in adsorbed reactants» ***OR*** activation energy lowered ✓ products desorbed ✓	*Accept "products released" for M3.*	**2 max**
4.	d		*Conduct electricity:* «delocalized/valence» electrons free to move «under potential difference» ✓ *Harder than pure metals:* atoms/ions of different sizes prevent layers «of atoms/ions» from sliding over one another ✓		**2**
4.	e		$2CO\,(g) \rightarrow C\,(s) + CO_2\,(g)$ ✓		**1**

Question			Answers	Notes	Total
5.	a		 correct bonding ✓ Cl atoms all on same side and alternate ✓	*Continuation bonds must be shown.* *Award **[1 max]** if less than or more than four units shown.* *Accept a stereo formula with all atoms and bonds shown.*	**2**
5.	b		«strong additional» absorption at 600–800 «cm^{-1}» ✓		**1**
5.	c		*Any two of:* embedded/fit between chains of polymers ✓ prevent chains from forming crystalline regions ✓ keep polymer strands/chains/molecules separated/apart ✓ increase space/volume between chains ✓ weaken intermolecular/dipole-dipole/London/dispersion/instantaneous dipole-induced dipole/van der Waals/vdW forces «between chains» ✓ increase flexibility/durability/softness ✓ make polymers less brittle ✓	*Accept "lowers density/melting point".*	**2 max**
5.	d		leach into foodstuffs/environment ***OR*** «unknown» health/environmental consequences ✓	*Accept "plasticizers cannot be recycled".*	**1**

Question			Answers	Notes	Total
5.	e		addition produces only the polymer **«*AND* more green»** ***OR*** addition has no by/side-product/condensation produces by-product/small molecules/HCl/NH_3 **«*AND* less green»** ***OR*** addition has high atom economy/condensation has lower atom economy **«*AND* less green»** ***OR*** condensation polymers **«**often**»** more biodegradable than addition polymers **«*AND* more green»** ✓	*Accept "if water produced by condensation **«AND** condensation and addition equally green**»**".* *Accept for addition "all of reactants change into products".*	**1**
5.	f		 ✓	*Continuation bonds must be shown.* *Do **not** accept condensed formula.*	**1**

Question			Answers	Notes	Total
6.	a		«$8 \times \frac{1}{8} + 6 \times \frac{1}{2} =$» 4 ✓		1
6.	b		$a =$ «$\frac{4r}{\sqrt{2}} = \frac{4 \times 1.97 \times 10^{-10}\ \text{m}}{\sqrt{2}} =$» 5.572×10^{-10} «m» ***OR*** volume of unit cell = «$(5.572 \times 10^{-10}\ \text{m})^3 \times 10^6 =$» 1.73×10^{-22} «cm^3» ✓ mass of unit cell =«$\frac{40.08\ \text{g mol}^{-1} \times 4}{6.02 \times 10^{23}\ \text{mol}^{-1}} =$» 2.66×10^{-22} «g» ✓ density = «$\frac{2.66 \times 10^{-22}\ \text{g}}{(5.572 \times 10^{-10})^3 \times 10^6}$ =» 1.54 «g cm^{-3}» ✓	*Award **[3]** for correct final answer.*	3

7.	a		«material with» no electrical resistance ✓		1
7.	b		Type 1 has sharper transition to superconductivity ✓	*Accept annotated plot of electrical resistance against temperature.*	1

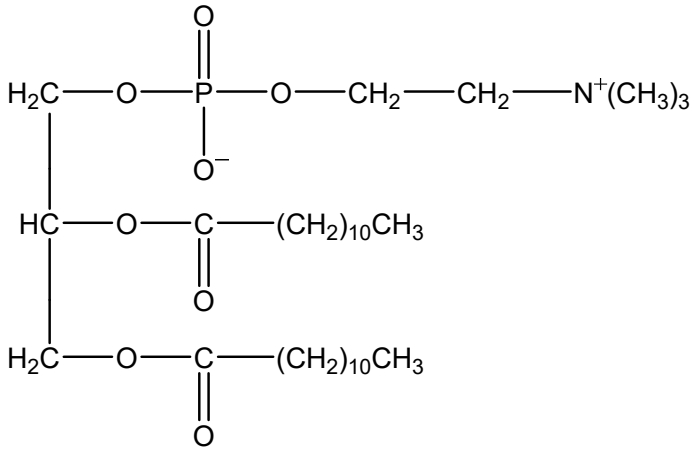
Question			Answers	Notes	Total
8.	a		*Any one of:* disrupt endocrine system ***OR*** compete for active sites of enzymes/cellular receptors ***OR*** form complexes with/inhibit enzymes ***OR*** denature proteins ***OR*** change shape of active site ✓ participate in redox reactions ***OR*** disturb normal redox balance «in cells» ✓ initiate «free» radical reactions «in electron transfer» ✓		**1 max**
8.	b		«$K_{sp} = 7.40 \times 10^{-14}$» $K_{sp} = [Pb^{2+}][CO_3^{2-}]$ ✓ $[Pb^{2+}]$ «$= \frac{7.40 \times 10^{-14}}{1.10 \times 10^{-4}}$» $= 6.73 \times 10^{-10}$ «mol dm^{-3}» ✓	*Award **[2]** for correct final answer.*	**2**
8.	c		*Any one of:* chelation «by EDTA/polydentate ligand anchored» ✓ ion exchange systems ✓ adsorption by «water» plants ✓	*Accept "use of zeolites".*	**1 max**

Option B — Biochemistry

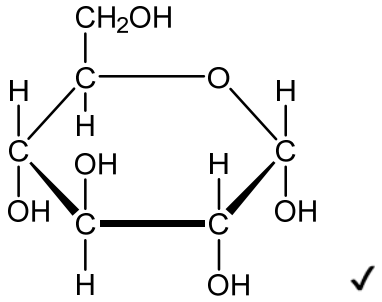
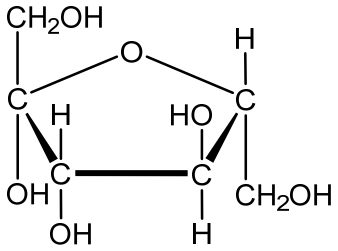
Question			Answers	Notes	Total
9.	a	i	β/beta pleated/sheet ✓		1
9.	a	ii	*One similarity:* hydrogen bonding ***OR*** attractions between C=O and N–H «on main chain» ✓ *One difference:* α-helix has hydrogen bonds between amino acid residues that are closer than β-pleated sheet ***OR*** H-bonds in α-helix parallel to helix axis ***AND*** perpendicular to sheet in β-pleated sheet ***OR*** α-helix has one strand ***AND*** β-pleated sheet has two «or more» strands ***OR*** α-helix is more elastic «since H-bonds can be broken easily» ***AND*** β-pleated sheet is less elastic «since H-bonds are difficult to break» ✓	*Accept a diagram which shows hydrogen bonding between O of C=O and H of NH groups for M1.* *Accept "between carbonyl/amido/amide/carboxamide" but not "between amino/amine" for M1.*	2
9.	b		enzyme denatured/ loss of 3-D structure/conformational change ***OR*** «interactions responsible for» for tertiary/quaternary structures altered ✓ shape of active site changes ***OR*** fewer substrate molecules fit into active sites ✓		2

Question			Answers	Notes	Total
9.	c		V_{max} unchanged ✓ at high substrate concentration substrate outcompetes inhibitor/need a higher substrate concentration to reach V_{max} ✓	*Accept suitable labelled diagram.*	**2**
9.	d	i	*Any two of:* surface water is warmer **«**so faster reaction rate**»**/more light/energy from the sun ✓ more oxygen **«**for aerobic bacteria/oxidation of oil**»** ✓ greater surface area ✓		**2 max**
9.	d	ii	*Any one of:* non-hazardous/toxic to the environment/living organisms ✓ energy requirements **«**during production**»** ✓ quantity/type of waste produced **«**during production**»** ***OR*** atom economy ✓ safety of process ✓	*Accept "use of solvents/toxic materials **«**during production**»**".* *Do **not** accept "more steps involved".*	**1 max**

Question			Answers	Notes	Total
10.	**a**	**i**	pK_{a2} ***AND*** pH of solution > pH of isoelectric point **«**as anion present**»** ***OR*** pK_{a2} ***AND*** zwitterion has lost H^+ to become anion **«**so in basic solution**»** ***OR*** pK_{a2} ***AND*** **«**only**»** anion **«**and zwitterion**»** present ✓		**1**
10.	**a**	**ii**	**«** $\text{pH} = 9.1 + \log\left[\frac{0.30}{0.60}\right]$ **»** **«**$= 9.1 + (-0.3)$**»** $= 8.8$ ✓		**1**
10.	**b**		sequence of bases in DNA ✓ codon/triplet code/each set of three bases codes for an amino acid ✓		**2**

Question			Answers	Notes	Total
11.	a	i	 phosphodiester correctly drawn ✓ both ester groups correctly drawn ✓	*Accept protonated phosphate.* *Accept phosphodiester in centre position.*	**2**
11.	a	ii	condensation ✓	*Accept "esterification".* *Accept "nucleophilic substitution/S_N".*	**1**
11.	b		phospholipid bilayer/double layer ***OR*** two layers of phospholipids ✓ polar/hydrophilic heads facing aqueous environment ***AND*** non-polar/ hydrophobic tails facing away from aqueous environment ✓	*Award **[2]** for a suitably labelled diagram.* *Award **[1]** for a correct but unlabelled diagram.* *Accept "polar/hydrophilic heads on outside **AND** non-polar/hydrophobic tails on inside" for M2.*	**2**

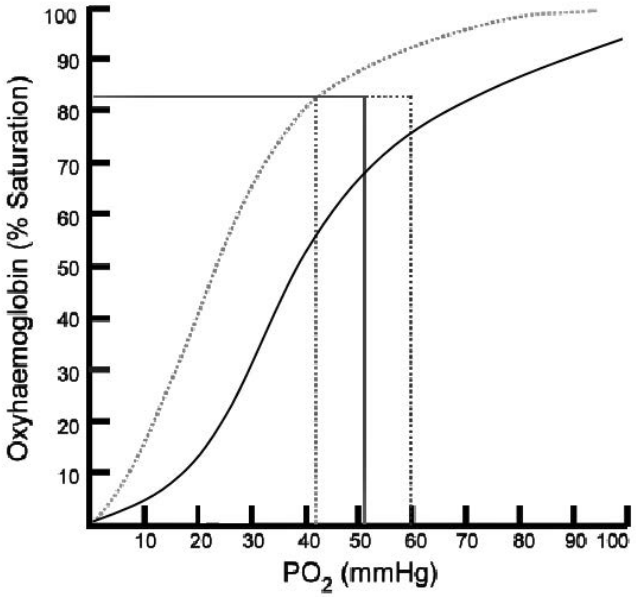
Question			Answers	Notes	Total
11.	c		long non-polar/hydrocarbon chain «and only one hydroxyl group» ***OR*** forms London/dispersion/van der Waals/vdW interactions with fat ✓	*Accept "alcohol/hydroxy/OH" for "hydroxyl" but **not** "hydroxide".*	**1**
11.	d		*Any one of:* atherosclerosis/cholesterol deposition «in artery walls» ✓ increases risk of heart attack/stroke/cardiovascular/heart disease/CHD ✓	*Accept "arteries become blocked/walls become thicker", "increases blood pressure", or "blood clots".* *Do **not** accept "high cholesterol".*	**1 max**

Question			Answers	Notes	Total
12.	a		acetal ***OR*** ether ✓	*Accept "glycosidic bond/linkage" but **not** "glucosidic".* *Do **not** accept "hemiacetal".*	**1**
12.	b		α-isomer ***AND*** hydroxyl group on carbon 1 and $-CH_2OH$ are trans ***OR*** α-isomer ***AND*** hydroxyl group on carbon 1 is below plane of ring ***OR*** α-isomer ***AND*** glycosidic linkage between rings is below plane of ring ✓	*Accept "ether linkage" for M3.*	**1**
12.	c		 ✓  ✓		**2**

Question			Answers	Notes	Total
13.	a		extensive conjugated system ***OR*** extensive delocalized bonding system ***OR*** extended system of alternating double and single bonds ✓ absorbs green ***OR*** complementary to red light ✓		**2**
13.	b	i	sigmoid/S-shaped ***OR*** as oxygen binds to one active site, shape of other active sites change ✓ affinity of other sites for oxygen increases/ability to bind oxygen is increased by initial binding of oxygen ***OR*** cooperative binding ✓	*Accept description of sigmoid/S-shaped curve if not stated for M1.*	**2**

(continued…)

(Question 13b continued)

Question			Answers	Notes	Total
13.	**b**	**ii**	 [Source: Ratznium, https://commons.wikimedia.org/wiki/File:Oxyhaemoglobin_dissociation_curve.png] curve to right of original ✓		**1**

Option C — Energy

Question			Answers	Notes	Total
14.			***Advantage*** *Any one of:* renewable ✓ predictable supply ✓ tidal barrage may prevent flooding ✓ effective at low speeds ✓ long life-span ✓ low cost to run ✓ ***Disadvantage*** *Any one of:* cost of construction ✓ changes/unknown effects on marine life ✓ changes circulation of tides in the area ✓ power output is variable ✓ limited locations where feasible ✓ equipment maintenance can be challenging ✓ difficult to store energy ✓	*Do **not** accept vague generalisations.* *Do **not** accept economic issues for both advantage and disadvantage.* *Do **not** accept sustainable.* *Accept "energy" or "electricity" for "power".*	**2 max**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>15.</td><td>a</td><td></td><td>
<table>
<tr><th>Fractional distillation:
Any two of: 1 max</th><th>Cracking:
Any two of: 1 max</th></tr>
<tr><td>physical process

separation of compounds by boiling point/vapour pressure

breaking intermolecular forces

different molar masses

does not use catalyst</td><td>chemical process

new compounds formed

increasing branching/ring formation

short hydrocarbon chains formed

breaking «and remaking»/changing covalent bonds
uses catalyst</td></tr>
</table>
</td><td>Award [1] for any two correct answers from one column OR one from each column.

Award [2] for any two correct from each column; eg: fractional distillation – any two correct award [1 max] AND cracking – any two correct, award [1 max].</td><td>2 max</td></tr>
<tr><td>15.</td><td>b</td><td></td><td>specific energy = «$\frac{4163\ \text{kJ mol}^{-1}}{86.2\ \text{g mol}^{-1}}$=» 48.3 «kJ g^{-1}» ✓

energy density = «48.3 kJ g^{-1} × 0.660 g cm^{-3} =» 31.9 «kJ cm^{-3}» ✓</td><td>Award [1 max] if either or both answers not expressed to three significant figures.</td><td>2</td></tr>
<tr><td>15.</td><td>c</td><td></td><td>Any two of:
«hydrocarbons are heated with» catalyst ✓

long chains break and reform
OR
branching/aromatisation occurs
OR
isomerisation/reforming/platforming/cracking ✓

zeolite separates branched from non-branched
OR
products are distilled
OR
«distillation» separates reformed and cracked products ✓</td><td>Accept a specific catalyst name or formula for M1 such as Pt/Re/Rh/Pd/Ir.</td><td>2 max</td></tr>
</table>

Question			Answers	Notes	Total
16.	a	i	$^{103}_{40}Zr$ ✓		1
16.	a	ii	minimum mass to «self-»sustain chain reaction ***OR*** if mass of fissile material is too small, too many neutrons produced pass out of the nuclear fuel ***OR*** at least one neutron produced causes further reaction ✓		1
16.	a	iii	*Any one of:* reduction in emission of greenhouse gases «from burning fossil fuels» ✓ economic independence/self-sufficiency «from crude oil/producing states» ✓ uranium is more abundant on Earth «in terms of total energy that can be produced from this fuel» than fossil fuels ✓	*Accept specific greenhouse gases (such as carbon dioxide/CO_2) but **not** pollutants or other general statements.*	1 max
16.	b		*Any one of:* fuel is inexpensive/readily available ✓ no/less radioactive waste is formed ✓ lower risk of accidents/large-scale disasters ✓ impossible/harder to use for making materials for nuclear weapons ✓ larger amounts of energy released per unit mass ✓ does not require a critical mass ✓ can be used continuously ✓	*Accept "higher specific energy for fusion".* *Do **not** accept "no/less waste produced for fusion".* *Accept specific example for a disaster.*	1 max
16.	c		mass difference between reactants and products ***AND*** $E = mc^2$ ✓		1

Question			Answers	Notes	Total
16.	**d**		«$N = N_0 e^{-\lambda t}$» λ«$= \frac{-\ln\left(\frac{N}{N_0}\right)}{t} = \frac{-\ln\left(\frac{4.0\times10^{-5}}{5.0\times10^{-5}}\right)}{31.4\text{ s}}$» $= 7.106 \times 10^{-3}\,\text{s}^{-1}$ ✓ «$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ =» 98/97.5 «s» ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
17.			***Strength*** *Any one of:* less flammable «than diesel» ✓ recycles carbon «lower carbon footprint» ***OR*** lower greenhouse gas emissions ✓ easily biodegradable «in case of spill» ✓ renewable ***OR*** does not deplete fossil fuel reserves ✓ economic security/availability in countries without crude oil ✓ ***Limitation*** *Any one of:* more difficult to ignite inside the engine «than diesel» ✓ more viscous «than diesel» ✓ lower energy content/specific energy/energy density ✓ uses food sources ***OR*** uses land that could be used for food ✓ «production is» more expensive ✓ less suitable in low temperatures ✓ increased NO_x emissions for biodiesel ✓ greenhouse gases still produced ✓	*Accept "«close to» carbon neutral", "produce less greenhouse gases/CO_2".* *Accept "engines have to be modified if biodiesel used" as limitation.* *Do **not** award marks for strength and limitation that are the same topic/concept.*	**2 max**

Question			Answers	Notes	Total
18.	a		bond length/C=O distance changes ***OR*** «asymmetric» stretching «of bonds» ***OR*** bond angle/OCO changes ✓ polarity/dipole «moment» changes ***OR*** dipole «moment» created «when molecule absorbs IR» ✓	*Accept appropriate diagrams.*	**2**
18.	b		*Any one of:* capture where produced «and store» ✓ use scrubbers to remove ✓ use as feedstock for synthesising other chemicals ✓ carbon credit/tax/economic incentive/fines/country specific action ✓ use alternative energy ***OR*** stop/reduce use of fossil fuels for producing energy ✓ use carbon reduced fuels «such as methane» ✓ increase efficiency and reduce energy use ✓	*Do **not** accept "planting more trees".* *Accept specific correct examples.*	**1 max**

Question			Answers	Notes	Total
19.	a		*Any three of:* $C_6H_{12}O_6\,(aq) + 6H_2O\,(l) \rightarrow 6CO_2\,(g) + 24H^+\,(aq) + 24e^-$ ***OR*** electrons released by oxidation of glucose ✓ enzymes «in bacteria» oxidize glucose ***OR*** «bacteria» transfer «released» electrons directly to anode ✓ $24H^+\,(aq) + 6O_2\,(g) + 24e^- \rightarrow 12H_2O\,(l)$ ***OR*** electrons consumed by reduction of oxygen ✓ PEM/membrane separates two half reactions ***OR*** PEM/membrane allows proton/H^+ transfer from anode to cathode ✓ electrons flow though external circuit ✓	*Accept* $4H^+\,(aq) + O_2\,(g) + 4e^- \rightarrow 2H_2O\,(l)$.	**3 max**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>19.</td><td>b</td><td></td><td>«$E = E^{\ominus} - \frac{RT}{nF} \times \ln Q$»

$\ln Q$ = «$\ln \frac{[Mg^{2+}]}{[Ag^{+}]^2} = \frac{0.0500}{0.100^2} = \ln 5.00$ =» 1.61 ✓

E = «$3.17\,V - \frac{8.31\,J\,K^{-1}\,mol^{-1} \times 298\,K}{2 \times 96\,500\,J\,V^{-1}\,mol^{-1}} \times \ln \frac{0.0500}{0.100^2} = 3.17 - 0.021 = +$»3.15 «V» ✓</td><td>Award [2] for correct final answer.</td><td>2</td></tr>
<tr><td>19.</td><td>c</td><td></td><td>Any one of:
<table><tr><th>Primary</th><th></th><th>Secondary</th></tr><tr><td>«electrode» materials cannot be reused/regenerated</td><td>AND</td><td>«electrode» materials can be regenerated/reused ✓</td></tr><tr><td>non-reversible reaction(s)</td><td>AND</td><td>reversible reaction(s) ✓</td></tr><tr><td>lower rate of self-discharge</td><td>OR</td><td>higher rate of self-discharge ✓</td></tr><tr><td>only lower current demands</td><td>OR</td><td>can deliver stronger current demands ✓</td></tr></table></td><td>Accept “primary cannot be recharged AND “secondary can be recharged”.</td><td>1 max</td></tr>
</table>

Question			Answers	Notes	Total
20.	**a**		*Semiconductors:* increases ✓ *Metals:* decreases ✓	*Accept any graph showing general increase for semiconductor.* *Accept any graph showing general decrease for metal.* *Accept a graph showing vertical section below transition temperature for a superconducting metal.*	**2**
20.	**b**		dye absorbs light ✓ electrons from «excited» dye pass to TiO_2/semiconductor/electrolyte/cell ***OR*** dye undergoes photo-oxidation ✓		**2**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
21.	a		*Therapeutic window:* range of dosage «over which a drug» provides the therapeutic/desired effect without causing adverse/toxic effects ✓ *Therapeutic index:* toxic dose of drug for 50 % of population divided by minimum effective dose for 50 % of population ***OR*** $\frac{\text{TD50}}{\text{ED50}}$ ✓	*M1 may be scored from a correctly labelled diagram.* *Do **not** accept reference to lethal dose used in therapeutic index in animal studies.*	**2**
21.	b		morphine has «two» hydroxyl groups ***AND*** diamorphine has «two» ester/ethanoate/acetate groups ***OR*** molecule of diamorphine is less polar than morphine ***OR*** groups in morphine are replaced with less polar/non-polar groups in diamorphine ✓ «less polar molecules» cross the blood–brain barrier faster/more easily ***OR*** diamorphine is more soluble in non-polar environment of CNS/central nervous system than morphine ✓	*Accept "alcohol/hydroxy" for "hydroxyl" but **not** "hydroxide".* *Accept "fats" for "lipid".* *Accept "heroin" for "diamorphine".*	**2**

Question			Answers	Notes	Total
22.	**a**		*Any one of:* 1050–1410 «cm^{-1} due to C–O» ✓ 1700–1750 «cm^{-1} due to C=O in acids and esters» ✓ 2500–3000 «cm^{-1} due to O–H in acids» ✓ 2850–3090 «cm^{-1} due to C–H in alkanes and arenes» ✓		**1 max**
22.	**b**	**i**	n(aspirin) «= n(NaOH) = $\frac{16.25\,cm^3}{1000} \times 0.100\,mol\,dm^{-3}$ »= 1.625×10^{-3} «mol» ✓ m(aspirin) «= $1.625 \times 10^{-3}\,mol \times 180.17\,g\,mol^{-1}$ »= 0.293 «g» ✓	*Award **[2]** for correct final answer.*	**2**
22.	**b**	**ii**	«$\frac{0.293\,g}{0.300\,g} \times 100\,\%$ »= 97.7 «%» ✓		**1**
22.	**c**		convert to a salt ***OR*** react with sodium hydroxide ✓	*Accept other reactions forming soluble salts.* *Accept "to ionize" but **not** "more polar".*	**1**
22.	**d**		synergistic effect/increased toxicity ***OR*** increased risk of stomach/intestines bleeding/ulcers/heartburn ***OR*** increased risk of liver toxicity/damage ***OR*** increased risk of nausea/vomiting ✓		**1**

Question			Answers	Notes	Total
23.	a	i	blocks/binds H2/histamine receptors «in cells of stomach lining» ***OR*** prevents histamine molecules binding to H2/histamine receptors «and triggering acid secretion» ✓		1
23.	a	ii	*Any two of:* ranitidine can be effective in treating ulcers «but antacid is not» ✓ ranitidine can prevent long-term damage «from overproduction of acid and antacid does not» ✓ ranitidine has a long-term effect «and antacid has short-term effect only» ✓ ranitidine does not affect ionic balance in body «and antacid does» ✓ ranitidine does not produce bloating/flatulence ✓	*Accept "ranitidine stops the over production of acid in the stomach while antacids neutralise the excess acid giving temporary relief" for M2.*	2 max
23.	b		«$\text{pH} = \text{p}K_a + \log\frac{[\text{A}^-]}{[\text{HA}]} = 10.32 + \log\frac{0.160}{0.200} = 10.32 - 0.097$» «pH =»10.22 ✓		1

Question			Answers	Notes	Total
24.	**a**		*Any one of:* alter cell's genetic material so that virus cannot use it to multiply ✓ prevent viruses from multiplying by blocking enzyme activity within host cell ***OR*** inhibit the synthesis of viral components by blocking enzymes inside the cell ✓ prevent viruses from entering **«**host**»** cell ***OR*** bind to cellular receptors targeted by viruses ***OR*** bind to virus-associated proteins/VAPs which target cellular receptors ***OR*** prevents removal of protein coat/capsid ***OR*** prevents injection of viral DNA/RNA into cell ✓ prevent/hinder the release of viruses from the cell ✓	*Accept "prevents synthesis of virus by host cell".* *Accept "alters RNA/DNA/genetic material of virus".* *Do **not** accept just "mimics nucleotides".*	**1 max**

Question			Answers	Notes	Total
24.	b		*Any two of:* viruses lack cell structure so difficult to target with drugs ✓ HIV is a retrovirus ***OR*** HIV genetic material is in the form of RNA instead of DNA ✓ HIV affects/destroys helper/T-cells which are necessary to fight infection ✓ HIV has great genetic diversity so difficult to produce «a» vaccine ✓ anti-retroviral agents are expensive so not everyone/country can afford them ✓ socio-cultural issues deter people from seeking treatment/prevention/diagnosis ***OR*** lack of education/conversation/stigma associated with being HIV-positive ✓ mutation of virus/HIV ✓ virus/HIV metabolism linked to that of host cell ✓ drugs harm host cell as well as virus/HIV ✓ HIV difficult to detect/remains dormant ✓		**2 max**

Question			Answers	Notes	Total
25.	**a**		*Any two of:* produced by genetically engineered/modified bacteria/*E. coli* ***OR*** sustainable because synthesized and not obtained from yew trees ✓ chiral auxiliaries **«**isolated and**»** reused ✓ one enantiomer produced ✓ toxicity/recycling of solvents/materials used ✓ overall yield/atom economy/waste generated ✓		**2 max**
25.	**b**		*Any two of:* **«**plane-**»** polarized light ***OR*** light passes through polarizer/polarizing filter ✓ enantiomers rotate plane of **«**plane-**»** polarized light **«**by equal angles**»** in opposite directions ✓ measure angle/direction of rotation ✓		**2 max**

Question			Answers	Notes	Total
26.	**a**		*Any two of:* can be readily "tagged" to variety of biologically active carriers **«**which will deliver it to specific locations for imaging uses**»** ✓ frequency of radiation is compatible with existing X-ray detection apparatus ✓ product of decay has low radioactivity/relatively short half-life/low total exposure to patient ✓ **«**but small**»** increased risk of cancer to patient ✓ must be made on site ✓	*Accept other valid answers outlining advantages or limitations of Tc-99m, such as "produces only LLW", "Tc is a transition element forming compounds in a variety of oxidation states", "gamma-radiation **«**can escape the body and**»** be detected by external sensors", "activity decreases quickly, so dose must be calculated prior to each injection".*	**2 max**
26.	**b**		***ALTERNATIVE 1*** $\frac{N(t)}{N_0} = \left(\frac{1}{2}\right)^{\frac{10}{6.0}}$ ✓ 31 **«**% remaining**»** ✓ ***ALTERNATIVE 2*** λ **«**$= \frac{\ln 2}{t_{\frac{1}{2}}}$**»** $= 0.1155$ hours^{-1} ✓ **«**$\frac{N}{N_0} \times 100 = e^{-\lambda t} \times 100 = 0.31498 \times 100$**»** 31 **«**% remaining**»** ✓	*M1 is for correct substitution of values.* *Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
27.	a		*Any three of:* ethanol **«**in breath**»** is oxidized **«**to ethanoic acid**»** ✓ electrons pass through external circuit/meter ✓ **«**to cathode where**»** O_2 is reduced ✓ current is proportional to alcohol concentration ✓	*Accept equations for oxidation of ethanol or reduction of oxygen.*	**3 max**
27.	b		*Bond:* C–O ***OR*** C–H ✓ *Reason:* cannot use O–H bonds as in water **«**found in breath**»** ✓	*Accept "C–O/C–H **«**bonds in molecules in breath**»** most likely to be in ethanol".* *Do **not** apply ECF here.*	**2**