

Markscheme

May 2019

Chemistry

Standard level

Paper 3

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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⁺] has increased «over time» OR acid concentration has decreased «as reacted with lead» OR surface lead has decrease/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 responses 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 experiment 5/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 = $5.0 \times 10^{-6} \text{ g kg}^{-1} \times 80.0 \text{ kg} \Rightarrow 4.0 \times 10^{-4} \text{ «g of lead»}$ ✓ «volume = $\frac{4.0 \times 10^{-4} \text{ g}}{1.5 \times 10^{-2} \text{ g dm}^{-3}} \Rightarrow 2.7 \times 10^{-2} / 0.027 \text{ «dm}^3\text{»}$ ✓	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	<p>ALTERNATIVE 1 colour ✓ Br₂/reactant is coloured «Br⁻ (aq)/product is not» ✓</p> <p>ALTERNATIVE 2 conductivity ✓ greater/increased concentration of ions in products ✓</p> <p>ALTERNATIVE 3 mass/pressure ✓ gas is evolved/produced ✓</p> <p>ALTERNATIVE 4 pH ✓</p> <p>methanoic acid is weak AND HBr is strong OR increase in [H⁺] ✓</p>	<p>Do not accept “changes in temperature” or “number of bubbles”.</p> <p>Do not accept “mass of products is less than mass of reactants”.</p>	2

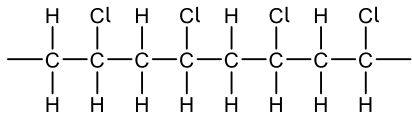
Question			Answers	Notes	Total
2.	c	i	<p>ALTERNATIVE 1 gas may leak/be lost/escape OR plunger may stick/friction «so pressure is greater than atmospheric pressure» OR syringe may be tilted «up» so plunger moves less «with gravity acting on plunger» OR CO₂ dissolved in water ✓ calculated rate lower ✓</p> <p>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 ✓</p>	<p><i>Calculated rate is lower or higher must be stated for M2.</i></p> <p><i>Do not accept “scale on syringe is inaccurate”, “errors in reading syringe”, or “bubbles in syringe”.</i></p>	2
2.	c	ii	human reaction time/delay «starting/stopping the stopwatch» ✓	<i>Do not accept “inaccurate stopwatch”.</i>	1

Section B

Option A — Materials

Question	Answers	Notes	Total
3.	<p><i>Shape of molecules:</i> linear OR rod «shaped» ✓</p> <p><i>Distribution:</i> no positional order AND «some» directional order ✓</p> <p><i>Effect of electric field:</i> «directional» order increases OR molecules align in same direction ✓</p>	<p><i>Accept “partly ordered”.</i></p>	<p>3</p>

Question		Answers	Notes	Total
4.	a	<p>moles of electrons $\llcorner = \frac{48\,250\text{ C}}{96\,500\text{ C mol}^{-1}} \llcorner = 0.5000 \llcorner \text{mol} \llcorner \checkmark$</p> <p>moles of aluminium $\llcorner = \frac{0.5000\text{ mol}}{3} \llcorner = 0.1667 \llcorner \text{mol} \llcorner \checkmark$</p> <p>mass of aluminium $\llcorner = 26.98\text{ g mol}^{-1} \times 0.1667\text{ mol} \llcorner = 4.50 \llcorner \text{g} \llcorner \checkmark$</p>	<i>Award [3] for correct final answer.</i>	3
4.	b	<p><i>Any two of:</i></p> <p>larger linear calibration \checkmark</p> <p>«accurate» detection of multiple elements/metals \checkmark</p> <p>«accurate» detection of elements in low concentration \checkmark</p> <p>temperature around 10 000 K atomises/ionises every material \checkmark</p>		2 max
4.	c	<p><i>Any two of:</i></p> <p>reactant(s) adsorb onto active sites/surface \checkmark</p> <p>bonds weakened/broken/stretched «in adsorbed reactants»</p> <p>OR</p> <p>activation energy lowered \checkmark</p> <p>products desorbed \checkmark</p>	<i>Accept “products released” for M3.</i>	2 max
4.	d	<p><i>Conduct electricity:</i></p> <p>«delocalized/valence» electrons free to move «under potential difference» \checkmark</p> <p><i>Harder than pure metals:</i></p> <p>atoms/ions of different sizes prevent layers «of atoms/ions» from sliding over one another \checkmark</p>		2
4.	e	$2\text{CO (g)} \rightarrow \text{C (s)} + \text{CO}_2\text{ (g)} \checkmark$		1

Question		Answers	Notes	Total
5.	a	 <p>correct bonding ✓ Cl atoms all on same side and alternate ✓</p>	<p><i>Continuation bonds must be shown.</i> <i>Award [1 max] if less than or more than four units shown.</i> <i>Accept a stereo formula with all atoms and bonds shown.</i></p>	2
5.	b	«strong additional» absorption at 600–800 «cm ⁻¹ » ✓		1
5.	c	<p>Any one of:</p> <p>HCl ✓ Cl₂ ✓ dioxins ✓ C ✓ CO ✓</p>	Accept names or formulas.	1 max
5.	d	<p>Any two of:</p> <p>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 ✓</p>	Accept “lowers density/melting point”.	2 max
5.	e	<p>leach into foodstuffs/environment OR «unknown» health/environmental consequences ✓</p>	Accept “plasticizers cannot be recycled”.	1

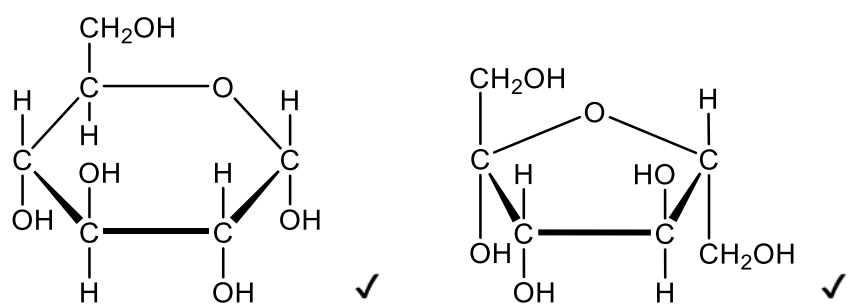
Option B — Biochemistry

Question			Answers	Notes	Total
6.	a	i	β /beta pleated/sheet ✓		1
6.	a	ii	<p><i>One similarity:</i> hydrogen bonding OR attractions between C=O and N-H ✓</p> <p><i>One difference:</i> 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» ✓</p>	<p>Accept a diagram which shows hydrogen bonding between O of C=O and H of NH groups for M1.</p> <p>Accept “between carbonyl/amido/amide/carboxamide” but not “between amino/amine” for M1.</p>	2
6.	b		<p>enzyme denatured/loss of 3-D structure/conformational change OR «interactions responsible for» tertiary/quaternary structures altered ✓</p> <p>shape of active site changes OR fewer substrate molecules fit into active sites ✓</p>		2

Question			Answers	Notes	Total
6.	c	i	<p><i>Any two of:</i></p> <p>surface water is warmer «so faster reaction rate»/more light/energy from the sun ✓</p> <p>more oxygen «for aerobic bacteria/oxidation of oil» ✓</p> <p>greater surface area ✓</p>		2 max
6.	c	ii	<p><i>Any one of:</i></p> <p>non-hazardous/toxic to the environment/living organisms ✓</p> <p>energy requirements «during production» ✓</p> <p>quantity/type of waste produced «during production»</p> <p>OR</p> <p>atom economy ✓</p> <p>safety of process ✓</p>	<p><i>Accept "use of solvents/toxic materials «during production»".</i></p> <p><i>Do not accept "more steps involved".</i></p>	1 max

Question			Answers	Notes	Total
7.	a	i	$ \begin{array}{c} \text{O} \\ \parallel \\ \text{H}_2\text{C}-\text{O}-\text{P}-\text{O}-\text{CH}_2-\text{CH}_2-\text{N}^+(\text{CH}_3)_3 \\ \\ \text{O}^- \\ \text{HC}-\text{O}-\text{C}-(\text{CH}_2)_{10}\text{CH}_3 \\ \parallel \\ \text{O} \\ \text{H}_2\text{C}-\text{O}-\text{C}-(\text{CH}_2)_{10}\text{CH}_3 \\ \parallel \\ \text{O} \end{array} $ <p>phosphodiester correctly drawn ✓ both ester groups correctly drawn ✓</p>	<p>Accept protonated phosphate. Accept phosphodiester in centre position.</p>	2
7.	a	ii	condensation ✓	<p>Accept "esterification". Accept "nucleophilic substitution/S_N".</p>	1

Question		Answers	Notes	Total
7.	b	<p>phospholipid bilayer/double layer OR two layers of phospholipids ✓</p> <p>polar/hydrophilic heads facing aqueous environment AND non-polar/hydrophobic tails facing away from aqueous environment ✓</p>	<p><i>Award [2] for a suitably labelled diagram.</i></p> <p><i>Award [1 max] for a correct but unlabelled diagram.</i></p> <p><i>Accept "polar/hydrophilic heads on outside AND non-polar/hydrophobic tails on inside for M2.</i></p>	2
7.	c	<p>carbohydrates less energy dense AND carbohydrates higher ratio of oxygen to carbon/more oxidized/less reduced ✓</p>		1
7.	d	<p>long non-polar/hydrocarbon chain «and only one hydroxyl group» OR forms London/dispersion/van der Waals/vdW interactions with fat ✓</p>	<p><i>Accept "alcohol/hydroxy/OH" for "hydroxyl" but not "hydroxide".</i></p>	1
7.	e	<p>atherosclerosis/cholesterol deposition «in artery walls» ✓ increases risk of heart attack/stroke/cardiovascular disease/CHD ✓</p>	<p><i>Accept "arteries become blocked/walls become thicker", "increases blood pressure", or "blood clots".</i></p> <p><i>Do not accept "high cholesterol".</i></p>	2

Question			Answers	Notes	Total
8.	a		acetal OR ether ✓	Accept "glycosidic bond/linkage" but not "glucosidic". Do not accept "hemiacetal".	1
8.	b				2

Option C — Energy

Question	Answers	Notes	Total
9.	<p>Advantage <i>Any one of:</i> renewable ✓ predictable supply ✓ tidal barrage may prevent flooding ✓ effective at low speeds ✓ long life-span ✓ low cost to run ✓</p> <p>Disadvantage <i>Any one of:</i> 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 ✓</p>	<p><i>Do not accept vague generalizations.</i></p> <p><i>Do not accept economic issues for both advantage and disadvantage.</i></p> <p><i>Do not accept sustainable.</i></p> <p><i>Accept “energy” or “electricity” for “power”.</i></p>	2 max

Question		Answers		Notes	Total
10.	a	<p>Fractional distillation:</p> <p>Any two of: 1 max</p> <p>physical process</p> <p>separation of compounds by boiling point/vapor pressure</p> <p>breaking intermolecular forces</p> <p>different molar masses</p> <p>does not use catalyst</p>	<p>Cracking:</p> <p>Any two of: 1 max</p> <p>chemical process</p> <p>new compounds formed</p> <p>increasing branching/aromatic ring formation</p> <p>short hydrocarbon chains formed</p> <p>breaking «and remaking»/changing covalent bonds</p> <p>uses catalyst</p>	<p>Award [1 max] for any two correct answers from one column OR one from each column.</p> <p>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].</p>	2 max
		<p>specific energy = « $\frac{4163 \text{ kJ mol}^{-1}}{86.2 \text{ g mol}^{-1}}$ » ⇒ 48.3 «kJ g⁻¹» ✓</p> <p>energy density = «48.3 kJ g⁻¹ × 0.660 g cm⁻³ » ⇒ 31.9 «kJ cm⁻³» ✓</p>		<p>Award [1 max] if either or both answers not expressed to three significant figures.</p>	

Question		Answers	Notes	Total
10.	c	<p>Any two of:</p> <p>«hydrocarbons are heated with» catalyst ✓</p> <p>long chains break and reform</p> <p>OR</p> <p>branching/aromatization occurs</p> <p>OR</p> <p>isomerisation/reforming/platforming/cracking ✓</p> <p>zeolite separates branched from non-branched</p> <p>OR</p> <p>products are distilled</p> <p>OR</p> <p>«distillation» separates reformed and cracked products ✓</p>	<p>Accept a specific catalysis name or formula for M1 such as Pt/Re/Rh/Pd/Ir.</p>	<p>2 max</p>

Question			Answers	Notes	Total
11.	a	i	$^{103}_{40}\text{Zr}$ ✓		1
11.	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
11.	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
11.	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 disasters.	1 max
11.	c		86.4 «years» ✓		1

Question			Answers	Notes	Total
12.	a		large/extensive «electronic» conjugation OR «contains» many alternate single and double bonds OR extended system of alternating double and single bonds ✓	<i>Student response must indicate a large or extended system to award mark.</i>	1

Question		Answers	Notes	Total
12.	b	<p>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 ✓</p> <p>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 ✓</p>	<p>Accept “«close to» carbon neutral”, “produce less greenhouse gases/CO₂”.</p> <p>Accept “engines have to be modified if biodiesel used” as limitation.</p> <p>Do not award marks for strength and limitation that are the same topic/concept.</p>	2 max

Question		Answers	Notes	Total
13.	a	<p>Any one of: methane, water, nitrous oxide/nitrogen(I) oxide, ozone, CFCs, sulfur hexafluoride ✓</p>	<p>Accept formulas. Do not accept "NO₂", "NO_x", "oxides of sulfur".</p>	1 max
13.	b	<p>bond length/C=O distance changes OR «asymmetric» stretching «of bonds» OR bond angle/OCO changes ✓</p> <p>polarity/dipole «moment» changes OR dipole «moment» created «when molecule absorbs IR» ✓</p>	<p>Accept appropriate diagrams.</p>	2
13.	c	<p>Any one of: capture where produced «and stored» ✓ use scrubbers to remove ✓ use as feedstock for synthesizing other chemicals ✓ carbon credit/tax/economic incentive/fines/country specific action ✓</p> <p>use alternative energy OR stop/reduce use of fossil fuels for producing energy ✓</p> <p>use carbon reduced fuels «such as methane» ✓ increase efficiency/reduce energy use ✓</p>	<p>Do not accept "planting more trees". Accept specific correct examples.</p>	1 max

Option D — Medicinal chemistry

Question			Answers	Notes	Total
14.	a		<p><i>Therapeutic window:</i> range of dosage «over which a drug» provides the therapeutic/desired effect without causing adverse/toxic effects ✓</p> <p><i>Therapeutic index:</i> toxic dose of drug for 50 % of population divided by minimum effective dose for 50 % of population</p> <p>OR</p> $\frac{TD50}{ED50} \checkmark$	<p><i>M1 may be scored from a correctly labelled diagram.</i></p> <p><i>Accept “difference between ED50/minimum effective/therapeutic dose «for 50 % of population» AND TD50/toxic dose «for 50 % of population»” for M1.</i></p> <p><i>Do not accept reference to lethal dose used in therapeutic index in animal studies.</i></p>	2
14.	b	i	<p>blocks pain impulses/binds with «opioid» receptors in <u>brain/CNS</u></p> <p>OR</p> <p>effective against strong pain</p> <p>OR</p> <p>sedate patients to reduce trauma ✓</p>	<p><i>Accept “effective against pain after surgery/cancer/following serious injury”.</i></p> <p><i>Accept “relieves anxiety/stress associated with severe/terminal illness”.</i></p>	1

(continued...)

(Question 14b continued)

Question			Answers	Notes	Total
14.	b	ii	<p>morphine has «two» hydroxyl groups AND diamorphine has «two» ester/ethanoate/acetate groups</p> <p>OR</p> <p>molecule of diamorphine is less polar than morphine</p> <p>OR</p> <p>groups in morphine are replaced with less polar/non-polar groups in diamorphine ✓</p> <p>«less polar molecules» cross the blood–brain barrier faster/more easily</p> <p>OR</p> <p>diamorphine is more soluble in non-polar environment of CNS/central nervous system than morphine ✓</p>	<p>Accept “alcohol/hydroxy” for “hydroxyl” but not “hydroxide”.</p> <p>Accept “fats” for “lipid”.</p> <p>Accept “heroin” for “diamorphine”.</p>	2
15.	a		<p>Any one of:</p> <p>1050–1410 «cm⁻¹ due to C–O» ✓</p> <p>1700–1750 «cm⁻¹ due to C=O in acids and esters» ✓</p> <p>2500–3000 «cm⁻¹ due to O–H in acids» ✓</p> <p>2850–3090 «cm⁻¹ due to C–H in alkanes and arenes» ✓</p>		1 max

Question			Answers	Notes	Total
15.	b	i	$n(\text{aspirin}) \llcorner n(\text{NaOH}) = \frac{16.25 \text{ cm}^3}{1000} \times 0.100 \text{ mol dm}^{-3} \llcorner = 1.625 \times 10^{-3} \llcorner \text{mol} \llcorner \checkmark$ $m(\text{aspirin}) \llcorner 1.625 \times 10^{-3} \text{ mol} \times 180.17 \text{ g mol}^{-1} \llcorner = 0.293 \llcorner \text{g} \llcorner \checkmark$	<i>Award [2] for correct final answer.</i>	2
15.	b	ii	$\llcorner \frac{0.293 \text{ g}}{0.300 \text{ g}} \times 100 \% \llcorner = 97.7 \llcorner \% \llcorner \checkmark$		1
15.	c		convert to a salt OR react with sodium hydroxide/NaOH \checkmark	<i>Accept other reactions forming soluble salts.</i> <i>Accept "to ionize" but not "more polar".</i>	1
15.	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 \checkmark		1
15.	e		<i>Any two of:</i> energy requirements «during production» \checkmark use of toxic materials «during production» \checkmark use of solvents «that are not recycled» \checkmark emission of toxic by-products \checkmark quantity of waste produced OR atom economy \checkmark	<i>Accept "E-factor/carbon efficiency/% of carbon in reactants vs products" for M1.</i> <i>Accept references to materials being/not being recycled for M3.</i>	2 max

Question			Answers	Notes	Total
16.	a	i	blocks/binds H ₂ /histamine receptors «in cells of stomach lining» OR prevents histamine molecules binding to H ₂ /histamine receptors «and triggering acid secretion» ✓		1
16.	a	ii	<i>Any two of:</i> 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 ✓	<i>Accept “ranitidine stops the over production of acid in the stomach while antacids neutralize the excess acid giving temporary relief”.</i>	2 max
16.	b		« $\text{pH} = \text{p}K_{\text{a}} + \log \frac{[\text{A}^{-}]}{[\text{HA}]} = 10.32 + \log \frac{0.160}{0.200} = 10.32 - 0.097$ » «pH =»10.22 ✓		1

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

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