Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2019

Chemistry

Standard level

Paper 3

27 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+}] 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 $= 5.0 \times 10^{-6}$ 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)/product 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

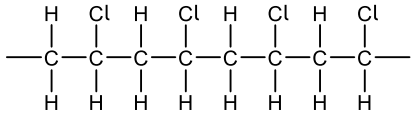
Question			Answers	Notes	Total
2.	**c**	**i**	***ALTERNATIVE 1*** gas may leak/be lost/escape ***OR*** plunger may stick/friction **«**so pressure is greater than atmospheric pressure**»** ***OR*** syringe may be tilted **«**up**»** so plunger moves less **«**with gravity acting on plunger**»** ***OR*** 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 ✓ *Effect of electric field:* **«**directional**»** order increases ***OR*** molecules align in same direction ✓	*Accept "partly ordered".*	**3**

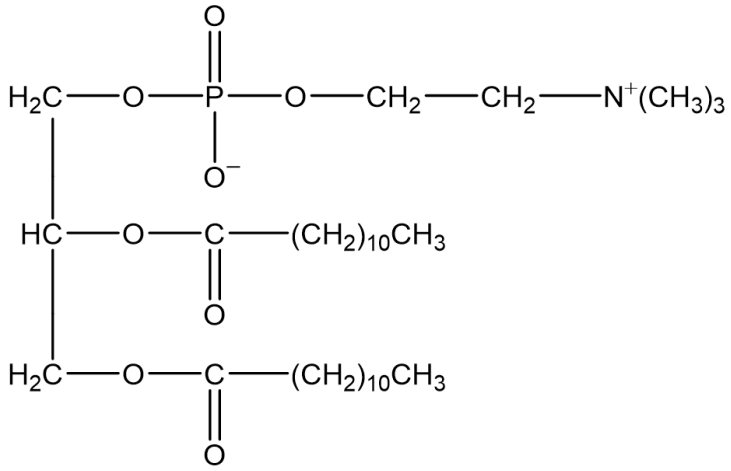
Question			Answers	Notes	Total
4.	**a**		moles of electrons **«**$= \frac{48\,250\text{ C}}{96\,500\text{ C mol}^{-1}}$**»** $= 0.5000$ **«mol»** ✓ moles of aluminium **«**$= \frac{0.5000\text{ mol}}{3}$**»** $= 0.1667$ **«mol»** ✓ mass of aluminium **«**$= 26.98\text{ g mol}^{-1} \times 0.1667\text{ mol}$**»** $= 4.50$ **«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 one of:* HCl ✓ Cl_2 ✓ dioxins ✓ C ✓ CO ✓	*Accept names or formulas.*	**1 max**
5.	**d**		*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.	**e**		leach into foodstuffs/environment ***OR*** **«**unknown**»** health/environmental consequences ✓	*Accept "plasticizers cannot be recycled".*	**1**

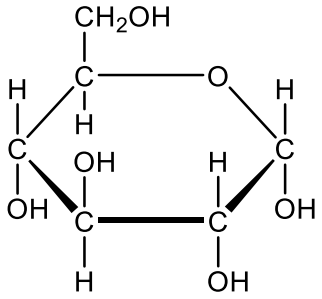
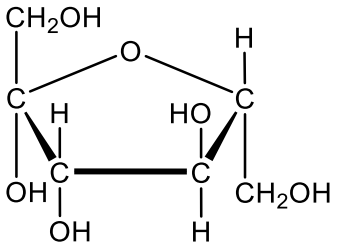
Option B — Biochemistry

Question			Answers	Notes	Total
6.	**a**	**i**	β/beta pleated/sheet ✓		**1**
6.	**a**	**ii**	*One similarity:* hydrogen bonding ***OR*** attractions between C=O and N–H ✓ *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**
6.	**b**		enzyme denatured/loss of 3-D structure/conformational change ***OR*** **«**interactions responsible for**»** tertiary/quaternary structures altered ✓ shape of active site changes ***OR*** fewer substrate molecules fit into active sites ✓		**2**

Question			Answers	Notes	Total
6.	**c**	**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**
6.	**c**	**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
7.	**a**	**i**	 phosphodiester correctly drawn ✓ both ester groups correctly drawn ✓	*Accept protonated phosphate.* *Accept phosphodiester in centre position.*	**2**
7.	**a**	**ii**	condensation ✓	*Accept "esterification".* *Accept "nucleophilic substitution/S_N".*	**1**

Question			Answers	Notes	Total
7.	**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 max]** for a correct but unlabelled diagram.* *Accept "polar/hydrophilic heads on outside **AND** non-polar/hydrophobic tails on inside for M2.*	**2**
7.	**c**		carbohydrates less energy dense ***AND*** carbohydrates higher ratio of oxygen to carbon/more oxidized/less reduced ✓		**1**
7.	**d**		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**
7.	**e**		atherosclerosis/cholesterol deposition **«**in artery walls**»** ✓ increases risk of heart attack/stroke/cardiovascular disease/CHD ✓	*Accept "arteries become blocked/walls become thicker", "increases blood pressure", or "blood clots".* *Do **not** accept "high cholesterol".*	**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.			***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 generalizations.* *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>10.</td><td>a</td><td></td><td>
<table>
<tr><th>Fractional distillation:</th><th>Cracking:</th></tr>
<tr><td>Any two of: 1 max
physical process
separation of compounds by boiling point/vapor pressure
breaking intermolecular forces
different molar masses
does not use catalyst</td><td>Any two of: 1 max
chemical process
new compounds formed
increasing branching/aromatic ring formation
short hydrocarbon chains formed
breaking «and remaking»/changing covalent bonds
uses catalyst</td></tr>
</table>
</td><td>Award [1] max 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>10.</td><td>b</td><td></td><td>specific energy $= \text{«}\frac{4163\ \text{kJ mol}^{-1}}{86.2\ \text{g mol}^{-1}}\text{»} = \text{»}\ 48.3\ \text{«kJ g}^{-1}\text{»}$ ✓

energy density $= \text{«}48.3\ \text{kJ g}^{-1} \times 0.660\ \text{g cm}^{-3} = \text{»}\ 31.9\ \text{«kJ cm}^{-3}\text{»}$ ✓</td><td>Award [1 max] if either or both answers not expressed to three significant figures.</td><td>2</td></tr>
</table>

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

Question			Answers	Notes	Total
11.	**a**	**i**	$^{103}_{40}Zr$ ✓		**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 ✓	*Student response must indicate a large or extended system to award mark.*	**1**

Question			Answers	Notes	Total
12.	b		***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
13.	**a**		*Any one of:* methane, water, nitrous oxide/nitrogen(I) oxide, ozone, CFCs, sulfur hexafluoride ✓	*Accept formulas.* *Do **not** accept "NO_2", "NO_x", "oxides of sulfur".*	**1 max**
13.	**b**		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**
13.	**c**		*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 ✓ use alternative energy ***OR*** stop/reduce use of fossil fuels for producing energy ✓ use carbon reduced fuels **«**such as methane**»** ✓ increase efficiency/reduce energy use ✓	*Do **not** accept "planting more trees".* *Accept specific correct examples.*	**1 max**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
14.	**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.* *Accept "difference between ED50/minimum effective/therapeutic dose **«**for 50 % of population**» AND** TD50/toxic dose **«**for 50 % of population**»" for M1.* *Do **not** accept reference to lethal dose used in therapeutic index in animal studies.*	**2**
14.	**b**	**i**	blocks pain impulses/binds with **«**opioid**»** receptors in <u>brain/CNS</u> ***OR*** effective against strong pain ***OR*** sedate patients to reduce trauma ✓	*Accept "effective against pain after surgery/cancer/following serious injury".* *Accept "relieves anxiety/stress associated with severe/terminal illness".*	**1**

(continued…)

(*Question 14b continued)*

Question			Answers	Notes	Total
14.	**b**	**ii**	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**

15.	**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**

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

Question			Answers	Notes	Total
16.	**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**
16.	**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 neutralize the excess acid giving temporary relief".*	**2 max**
16.	**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
17.	**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
17.	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**