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CHEMISTRY

Higher Level

Paper 3

OPTION C – HUMAN BIOCHEMISTRY

C1. (a) Retinol will contain an —OH (alkanol) group (*[1]*).
Retinal will contain a —CHO (alkanal) group (*[1]*). ***[2]***
(If both alkanol and alkanal are given but no structures award [1])

(b) **Two pairs of electrons (four electrons)** between the two carbon atoms. ***[1]***

(c) M_r for retinol $= (19 \times 12.01) + (30 \times 1.01) + (1 \times 16.00) = 274.5$ ***[1]***
Concentration is $0.30 \ g \ dm^{-3}$ which is $1.1 \times 10^{-3} \ mol \ dm^{-3}$. ***[1]***
(accept $1.09 \times 10^{-3} \ mol \ dm^{-3}$)

(d) More fat soluble. ***[1]***
Because the polar O—H bond will be insignificant compared to the bulky non-polar
'tail' of the molecule. ***[1]***
OR Because there is a very low concentration (of retinol in the blood).
OR Non-polar hydrophobic chain will be more soluble in fat than polar water.

C2. (a) Iodine. ***[1]***

(b) *Any **two** from:* acid, —COOH; amine, —NH$_2$; alkoxyalkane (ether), —O—; ***[4]***
(do not accept amide for —NH$_2$)

*(Give [1] for each correct name and [1] for each correct formula. Award no marks for
C_6H_5 – phenyl.)*

(c) Hormones are chemical messengers **OR** substances that regulate bodily processes such ***[1]***
as growth and metabolism.
Hormones are transported by the blood stream. ***[1]***

(d) Thyroxine regulates the rate at which cells use oxygen **OR** controls the rate of
carbohydrate metabolism **OR** controls rate of protein synthesis and breakdown **OR**
stimulates energy production in cells. ***[1]***

C3. (a) In RNA the pentose sugar is a ribose, in DNA it is a deoxyribose (contains one less O atom). *[1]*

RNA contains the base uracil in place of the thymine found in DNA. *[1]*

(Do not accept RNA single strand, DNA double strand)

(b) Condensation (*accept* phosphodiesterification or esterification). *[1]*

(c) They are held together by hydrogen bonds. *[1]*
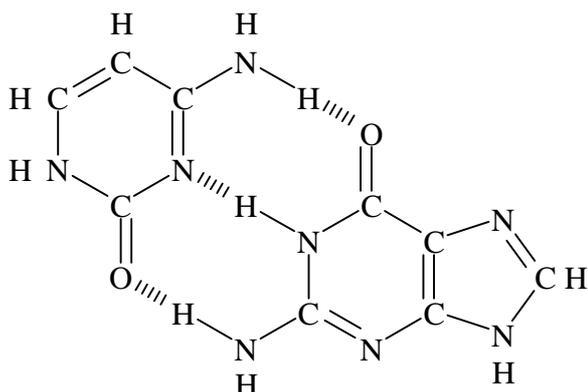
[2]

(Award [1] for correctly showing one or two hydrogen bonds and both marks for showing all three.)

(d) DNA profiling is the name given to the technique that can identify an individual with a high degree of certainty from a sample of the individual's genetic material. *[1]*

The lengths of each repeated sequence of bases (minisatellites) can be made visible by the use of DNA probes. *[1]*

The probe is labelled with radioactive ^{32}P, mixed with the individuals' DNA and exposed on photographic film (accept radioactive or fluorescent paint) or other suitable method of detection. *[1]*

Forensic uses (*e.g.* identifying rapists) **OR** paternity suits *etc*. *[1]*

OPTION D – ENVIRONMENTAL CHEMISTRY

D1. (a)   1000:1 *(do not accept 1:1000)*   *[1]*

(b)   Sulfuric acid (accept sulfuric(IV) acid or sulfurous acid).   *[1]*

(No mark if just the formula is given.)

$S + O_2 \rightarrow SO_2$ **OR** $2SO_2 + O_2 \rightarrow 2SO_3$ *[1]*
$SO_2 + H_2O \rightarrow H_2SO_3$ **OR** $SO_3 + H_2O \rightarrow H_2SO_4$ *[1]*
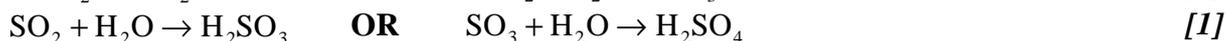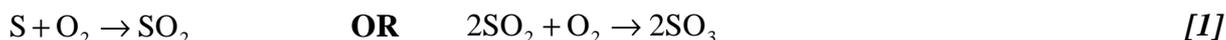
(c)   Nitric acid (accept nitrous acid or nitric(III) acid).   *[1]*

(Award [1] each for any two different ways, for example:)

- Use a catalytic converter;
- use a richer petrol:air mixture;
- car sharing;
- switching to a different fuel such as solar power or electricity *etc;*
- thermal exhaust system;
- increase the use of public transport.   *[2]*

(d) $CaCO_3 + 2H^+ \rightarrow Ca^{2+} + CO_2 + H_2O$ (accept H_2CO_3).   *[1]*

(Accept the full equation with either nitric or sulfuric acid.)

D2. (a)   (i)   As the temperature increases the solubility of oxygen decreases.   *[1]*

(ii)   As organic pollutants decompose they use up available oxygen so the amount of dissolved oxygen decreases.   *[1]*

(iii) Nitrates and phosphates act as nutrients and increase the growth of algae. As the algae die they use up dissolved oxygen (eutrophication).   *[1]*

(b)   The BOD is the quantity of oxygen (in ppm) utilised when the organic matter in a fixed volume of water is decomposed biologically over a set time period (usually five days).

[1]

(c)   Amount of $Na_2S_2O_3$ in 10 cm^3 of 0.100 mol dm^{-3} $Na_2S_2O_3$ is $\dfrac{10}{1000} \times 0.100 = 1.00 \times 10^{-3}$ moles.   *[1]*

One mole of O_2 reacts to give two moles of MnO_2 which give two moles of I_2 which react with four moles of $S_2O_3^{2-}$ so that the amount of oxygen present in 1000 cm^3 is $\dfrac{1}{4} \times 1.00 \times 10^{-3} = 2.50 \times 10^{-4}$ moles.   *[1]*

Mass of 2.50×10^{-4} moles of O_2 is $32 \times 2.50 \times 10^{-4} = 8.00 \times 10^{-3}$ g.
Concentration of dissolved oxygen is 8.00×10^{-3} g dm^{-3} (or 8 mg dm^{-3}).   *[1]*

D3. (a) $E = \dfrac{hc}{\lambda}$ for one molecule so that $E = \dfrac{hcL}{\lambda}$ for one mole of molecules. *[1]*

$$\lambda = \frac{hcL}{E} = \frac{(6.626 \times 10^{-34}) \times (2.998 \times 10^{8}) \times (6.022 \times 10^{23})}{4.96 \times 10^{5}}$$ *[1]*

$\quad = 2.41 \times 10^{-7}$ m (241 nm) *[1]*

(No double jeopardy if avogadro constant is left out.)

(b)
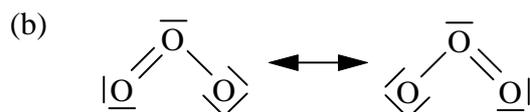
or delocalised structure showing π bond
(do not penalise if non-bonding pairs are not shown) *[1]*

The bond is **weaker** in ozone as it is equivalent to about 1.5 bonds rather than the double bond found in oxygen (so requires less energy/longer wavelength to break). *[1]*

(c) (i) The CCl_2F_2 is decomposed into chlorine radicals by ultra-violet light.

$$CCl_2F_2 \rightarrow CClF_2\bullet + Cl\bullet$$ *[1]*

Chlorine radicals react with ozone to form oxygen and a chlorine monoxide radical.

$$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$$ *[1]*

The chlorine radical is regenerated to react again by reaction of ClO with $O\bullet$.

$$ClO\bullet + O\bullet \rightarrow Cl\bullet + O_2$$ *[1]*

(ii) During the Antarctic winter it is thought the very small amounts of water vapour present freeze into ice crystals. *[1]*
On the surface of these ice crystals reactions occur to produce species such as Cl_2. When the winter is over the sun converts this into chlorine radicals $Cl_2 \rightarrow 2Cl\bullet$.

(Award [1] for ice crystals and [1] for act as catalyst) *[1]*

OPTION E – CHEMICAL INDUSTRIES

E1. (a) (i)   Carbon.   *[1]*

(ii)   Contains higher percentage of iron.   *[1]*

(b) (i)   Oxygen and powdered lime (calcium oxide / calcium carbonate).   *[2]*
(do not accept metals such as chromium)

(ii)   The impurities are oxidised **OR** oxidation takes place.   *[1]*
The oxidised impurities combine with the lime to form slag **OR** an acid–base
reaction takes place (accept equation).   *[1]*

(c)   It is more expensive to produce aluminium from its ores as it requires more energy
(even though Al is more abundant in the earth's crust than Fe).   *[1]*

E2. (a)   Crude oil was formed from marine organisms which contained sulfur (in their amino
acids).   *[1]*

(b)   Sulfur can poison many of the catalysts used in the refining processes (by reacting
irreversibly with their reactive sites).   *[1]*
OR   When the oil is burned SO_2 is produced which leads to acid rain.

(c) $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$ *(accept other balanced combinations of an alkane and an
alkene)*.   *[1]*
Larger molecules are broken down into smaller more useful molecules (the alkane is   *[1]*
used as gasoline and the alkene as feedstock for polymers).

(d)   Isomerisation involves **rearrangement** to form another isomer.   *[1]*
Alkylation involves the **combination** of alkanes and alkene (to form higher-grade
gasolines).   *[1]*

(e) (i) $C_6H_{14} \rightarrow C_6H_6 + 4H_2$ *[1]*

(ii)   Haber process (manufacture of ammonia).   *[1]*

E3.   Anode: Ti (or Pt) (*[1]*). Cathode: steel (*[1]*).
Diaphragm: asbestos (*[1]*).
At anode $2Cl^- \rightarrow Cl_2 + 2e^-$ (*[1]*).
At cathode $2H_2O + 2e^- \rightarrow 2OH^- + H_2$ (*[1]*). *(accept $2H^+ + 2e \rightarrow H_2$)*
The mercury from the Hg cell can escape into the environment causing mercury poisoning
(Minamata disease) (*[1]*).
Any two from: PVC, bleaching paper, disinfecting swimming pools, formation of inorganic
chemicals, solvent, refrigerants (*[2]*).
The UV light breaks the C—Cl bond (homolytically) to give Cl• radicals (*[1]*).
Cl• radicals react with ozone to give oxygen (*[1]*).   *[10]*

OPTION F – FUELS AND ENERGY

F1. (a) Methane / CH_4.   *[1]*

   (b) Carbon monoxide **OR** hydrogen. *(accept correct formulas)*   *[1]*

   (c) Any **two** from:
   - particulates (soot);
   - C_xH_y (accept HC or hydrocarbons);
   - CO (do not accept SO_x or NO_x).   *[2]*

   (d) Biomass is produced (continuously) from waste products or quick growing crops, (therefore there is no need to use foreign exchange to import oil or other fuels).   *[1]*
   OR Because fossil fuels are running out.

F2. (a) Splitting of an (unstable) nucleus.   *[1]*

   (b) There is a small mass loss which is converted into a large amount of energy.   *[1]*

   (c)

X	**n**	b	**1**
Y	**Pu**	c	**0**
Z	**e**	d	**0**
a	**92**	e	**−1**

                                                                                                                                                      [4]

   *(Award [½] for each, round **down**.)*

   (d) To prevent radioactivity from escaping.   *[1]*
   Closed loop primary coolant: water, heavy water, sodium, CO_2.   *[1]*

   (e) $\dfrac{1.2 \times 10^{-12}}{1.5 \times 10^{-13}} = 8 = 2^n$ therefore number of half-lives (n) is 3.   *[1]*

   Age of object is $3 \times 5730 = 1.7 \times 10^4$ years (17 190 years).   *[1]*

F3. Photons from sunlight provide sufficient energy *[1]* to release an electron *[1]* from its bonding position so that it can move freely *[1]* throughout the crystal lattice thus making silicon an electrical conductor. *[3]*

Disadvantages: Obtaining pure silicon is an expensive process. *[1]*
                           Conversion of sunlight to electricity is not very efficient. *[1]*

Silicon can be doped with a Group 3 element (Ga or In). *[1]*
This introduces holes which can be regarded as positive carriers of electricity (p-type doping). *[1]*

Silicon can also be doped with a Group 5 element (As). *[1]*
This introduces an extra electron which increases the electrical conductivity (n-type doping).
[1]

Both processes increase the conductivity of the silicon
because less energy is needed to get extra electrons or holes moving (*i.e.* reduces the ionisation energy).

[1]

OPTION G – MODERN ANALYTICAL CHEMISTRY

G1. (a) Monochromatic means all having the same frequency/wavelength.   *[1]*
The angle of diffraction depends on the frequency/wavelength.   *[1]*
So that, if the X-rays did not all have the same wavelength, there would not be a single diffraction angle.   *[1]*

(b) $n\lambda = 2d\sin\theta$; $d = \dfrac{n\lambda}{2\sin\theta}$; $d = \dfrac{1\times154\times10^{-12}}{2\times\sin32.3}$.   *[1]*

$d = 144\times10^{-12} = 144$ pm   *[1]*

(c) (i) One at centre plus $8\times\dfrac{1}{8}$ on corners means **two** chromium atoms.   *[1]*

(ii) Volume of one mole of Cr is $6.02\times10^{23}\times\dfrac{1}{2}\times(288\times10^{-12})^3$
$= 7.19\times10^{-6}$ m^3 *[1]*

Density is $\dfrac{m}{V} = \dfrac{52.00}{7.19\times10^{-6}\text{ g m}^{-3}} = 7.23\times10^6$ g m^{-3} $(= 7.23$ g cm$^{-3})$ *[1]*

(N.B. If 150 pm taken as separation of layers density is 6.40 g cm^{-3}.)

(d) (i) Solid.   *[1]*

(ii) Hydrogen; their electron density is too low.   *[2]*

(iii) The electron density is quite high indicating covalent bonding.   *[1]*

(e) (i) The energy of the quantum of radiation, given by $E = hf$ *[1]*
must be equal to the difference in the energy between the two states of the particle.   *[1]*

(ii) Changes in rotation involve smaller changes of energy than either electronic or vibrational changes.   *[1]*

G2. Steady gas flow (*[1]*) through a packed column (*[1]*). The sample is injected into the gas flow (*[1]*) and different compounds reach the detector at different times (*[1]*). The detector can operate on changes in thermal conductivity of the gas, or changes in the electrical conductivity of the flame as it is burnt (*[1]*).
Pesticide *B* is more strongly absorbed by the packing (*[1]*) so that it elutes after pesticide *A* (*[1]*). If the temperature were higher all the pesticides would elute more rapidly (*[1]*).
GLC is generally more sentitive, and hence smaller samples are required than HPLC (*[1]*), but it can only be used with substances which are volatile (*[1]*).   *[10]*

OPTION H – FURTHER ORGANIC CHEMISTRY

H1. (a) The melting point is determined by the strength of the intermolecular forces of attraction. *[1]*
Both isomers exhibit intermolecular hydrogen bonding but this is weaker in the 1,2-isomer as intramolecular hydrogen bonding also occurs. *[1]*

(b) In the 1,2-isomer the two alkanoic acid groups are aligned so that a molecule of water can be eliminated. In the 1,4-isomer the two acid groups are far apart from each other. *[1]*
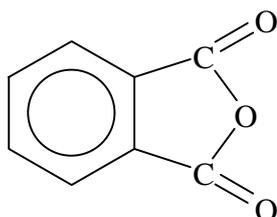
[1]

H2. (a) Electrophilic substitution. *[1]*

(b) It protonates the nitric acid (or it helps to form NO_2^+). *[1]*

(Accept a suitable equation *e.g.* $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+$
OR $NO_2^+ + H_2O + HSO_4^-$)

(c) The nitro- group is electron withdrawing. *[1]*
This decreases the electron density over the benzene ring making it less reactive towards electrophiles. *[1]*

(d) (i) A resonance hybrid lies inbetween the various Lewis structure representations.
[1]

(ii) The electron withdrawing nitro- group will tend to destabilise the carbocation when the positive charge is on the carbon atom containing the nitro- group. *[1]*
This only occurs in the resonance hybrid forms of the 2- and the 4- intermediates and so the 3- substitution will occur as the intermediate is more likely to be formed. *[1]*

(e) The 1,3-dinitrobenzene made by the student was not pure. *[1]*

H3. (a) Silver bromide (AgBr) (accept equation $Ag^+ + Br^- \rightarrow AgBr$) *[1]*

(b) The bromine is covalently bonded to the carbon atom so no bromide ions are present.

[1]

(c) Substitution occurs which releases the bromide ions. *[1]*

(d) The non-bonded pair of electrons on the bromine can delocalise with the electrons in the benzene ring (making the C—Br bond stronger so less able to break). *[1]*

OR The delocalised electrons from the benzene ring repel nucleophiles (and prevent them from reacting with the carbon atom bonded to the bromine).

(e)

[2]
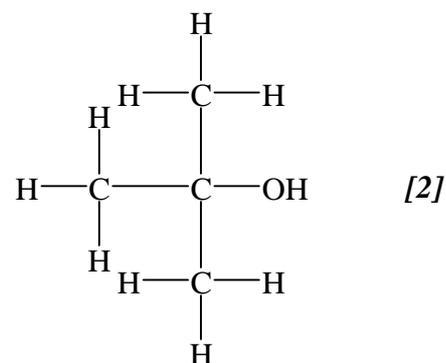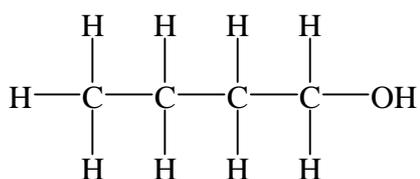
Rate = $k[1\text{-}\text{bromobutane}][OH^-]$ *[1]*
Rate = $k[2\text{-}\text{bromo}\text{-}2\text{-}\text{methylpropane}]$ *[1]*

[1]

[1]

$(CH_3)_3C—Br \xrightarrow{\text{(slow)}} (CH_3)_3C^+ + Br^-$ *[1]*
$(CH_3)_3C^+ + OH^- \rightarrow (CH_3)_3COH$ *[1]*
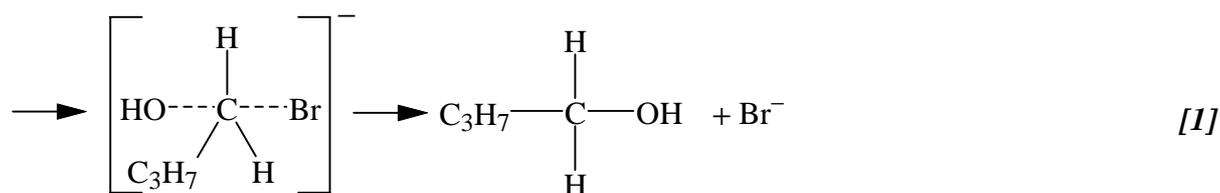
1-bromobutane, unlike 2-bromo-2-methylpropane, cannot dissociate into ions as a primary carbocation is less stable than a tertiary carbocation **OR** the transition state containing five groups around the central carbon ion cannot be formed in the case of 2-bromo-2-methylpropane due to steric hindrance. *[1]*