

# **MARKSCHEME**

**November 2000**

**CHEMISTRY**

**Higher Level**

**Paper 3**

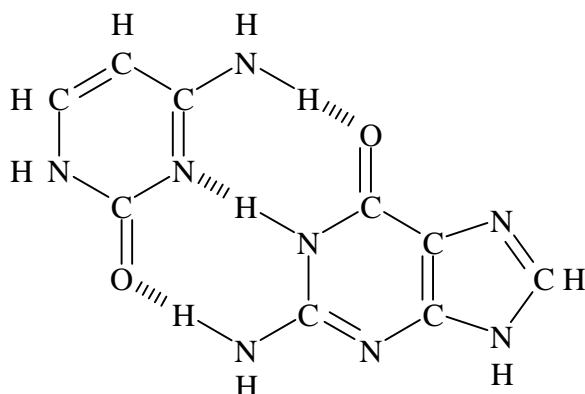
**OPTION C – HUMAN BIOCHEMISTRY**

- 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  $0.30 \text{ g dm}^{-3}$  which is  $1.1 \times 10^{-3} \text{ mol dm}^{-3}$ . *[1]*  
(accept  $1.09 \times 10^{-3} \text{ mol dm}^{-3}$ )
- (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<sub>2</sub>; alkoxyalkane (ether), —O—; *[4]*  
(do not accept amide for —NH<sub>2</sub>)  
  
(Give *[1]* for each correct name and *[1]* for each correct formula. Award no marks for C<sub>6</sub>H<sub>5</sub> – phenyl.)
- (c) Hormones are chemical messengers **OR** substances that regulate bodily processes such as growth and metabolism. *[1]*  
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.)*

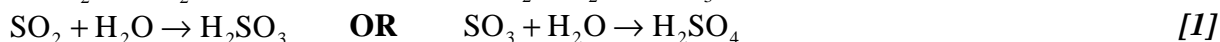
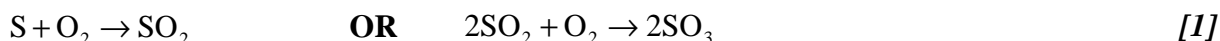
- (d) DNA profiling is the name given to the technique that can identify an individual with a high degree of certainty from a sample of the individual's genetic material. [1]  
 The lengths of each repeated sequence of bases (minisatellites) can be made visible by the use of DNA probes. [1]  
 The probe is labelled with radioactive  $^{32}\text{P}$ , 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.*)



(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  $10 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3}$   $Na_2S_2O_3$  is  $\frac{10}{1000} \times 0.100 = 1.00 \times 10^{-3}$  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  $1000 \text{ cm}^3$  is  $\frac{1}{4} \times 1.00 \times 10^{-3} = 2.50 \times 10^{-4}$  moles. [1]

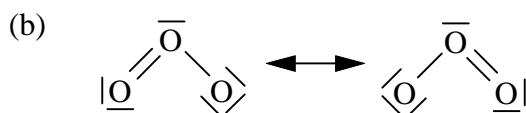
Mass of  $2.50 \times 10^{-4}$  moles of  $O_2$  is  $32 \times 2.50 \times 10^{-4} = 8.00 \times 10^{-3} \text{ g}$ .  
Concentration of dissolved oxygen is  $8.00 \times 10^{-3} \text{ g dm}^{-3}$  (or  $8 \text{ mg dm}^{-3}$ ). [1]

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

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

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

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



or delocalised structure showing  $\pi$  bond

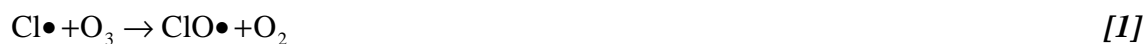
(do not penalise if non-bonding pairs are not shown) [1]

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  $\text{CCl}_2\text{F}_2$  is decomposed into chlorine radicals by ultra-violet light.



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



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



(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  $\text{Cl}_2$ . When the winter is over the sun converts this into chlorine radicals  $\text{Cl}_2 \rightarrow 2\text{Cl}\bullet$ .

(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  $\text{SO}_2$  is produced which leads to acid rain.
- (c)  $\text{C}_{10}\text{H}_{22} \rightarrow \text{C}_8\text{H}_{18} + \text{C}_2\text{H}_4$  (accept other balanced combinations of an alkane and an alkene). [1]  
Larger molecules are broken down into smaller more useful molecules (the alkane is used as gasoline and the alkene as feedstock for polymers). [1]
- (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)  $\text{C}_6\text{H}_{14} \rightarrow \text{C}_6\text{H}_6 + 4\text{H}_2$  [1]
- (ii) Haber process (manufacture of ammonia). [1]
- E3.** Anode: Ti (or Pt) ([1]). Cathode: steel ([1]).  
Diaphragm: asbestos ([1]).  
At anode  $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$  ([1]).  
At cathode  $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{OH}^- + \text{H}_2$  ([1]). (accept  $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ )  
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  $\text{Cl}\bullet$  radicals ([1]).  
 $\text{Cl}\bullet$  radicals react with ozone to give oxygen ([1]). [10]

**OPTION F – FUELS AND ENERGY**

**F1.** (a) Methane / CH<sub>4</sub>. [1]

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

(c) Any **two** from:  
 • particulates (soot);  
 • C<sub>x</sub>H<sub>y</sub> (accept HC or hydrocarbons);  
 • CO (do not accept SO<sub>x</sub> or NO<sub>x</sub>). [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	<b>n</b>	b	<b>1</b>
Y	<b>Pu</b>	c	<b>0</b>
Z	<b>e</b>	d	<b>0</b>
a	<b>92</b>	e	<b>–1</b>

[4]

(Award [½] for each, round **down**.)

(d) To prevent radioactivity from escaping. [1]

Closed loop primary coolant: water, heavy water, sodium, CO<sub>2</sub>. [1]

(e)  $\frac{1.2 \times 10^{-12}}{1.5 \times 10^{-13}} = 8 = 2^n$  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]*



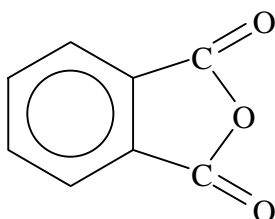
**OPTION G – MODERN ANALYTICAL CHEMISTRY**

- 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)  $n\lambda = 2d \sin \theta$ ;  $d = \frac{n\lambda}{2 \sin \theta}$ ;  $d = \frac{1 \times 154 \times 10^{-12}}{2 \times \sin 32.3}$ . [1]  
 $d = 144 \times 10^{-12} = 144 \text{ pm}$  [1]
- (c) (i) One at centre plus  $8 \times \frac{1}{8}$  on corners means **two** chromium atoms. [1]  
 (ii) Volume of one mole of Cr is  $6.02 \times 10^{23} \times \frac{1}{2} \times (288 \times 10^{-12})^3$   
 $= 7.19 \times 10^{-6} \text{ m}^3$  [1]  
 Density is  $\frac{m}{V} = \frac{52.00}{7.19 \times 10^{-6} \text{ g m}^{-3}} = 7.23 \times 10^6 \text{ g m}^{-3} (= 7.23 \text{ g cm}^{-3})$  [1]  
*(N.B. If 150 pm taken as separation of layers density is 6.40 g cm<sup>-3</sup>.)*
- (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 sensitive, 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 alkanolic 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  $\text{NO}_2^+$ ). [1]

(Accept a suitable equation *e.g.*  $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{NO}_3^+$   
**OR**  $\text{NO}_2^+ + \text{H}_2\text{O} + \text{HSO}_4^-$ )

- (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  $\text{Ag}^+ + \text{Br}^- \rightarrow \text{AgBr}$ ) [1]

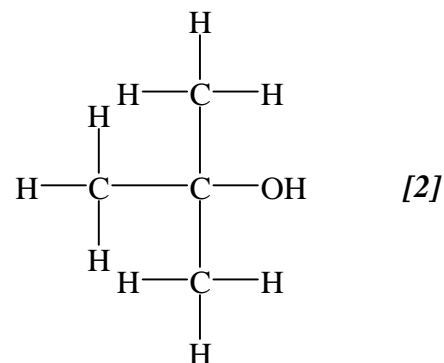
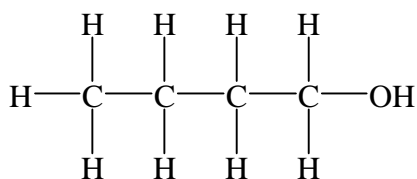
(b) The bromine is covalently bonded to the carbon atom so no bromide ions are present. [1]

(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]

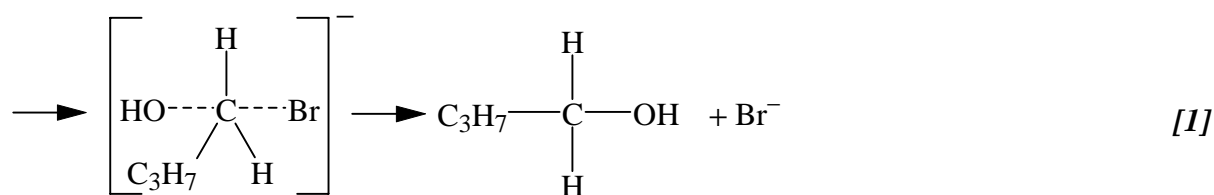
**OR** The delocalised electrons from the benzene ring repel nucleophiles (and prevent them from reacting with the carbon atom bonded to the bromine).

(e)



Rate =  $k[1\text{-bromobutane}][\text{OH}^-]$  [1]

Rate =  $k[2\text{-bromo-2-methylpropane}]$  [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.