IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

MARKSCHEME

May 2005

CHEMISTRY

Higher Level

Paper 3

21 pages

Subject Details: Chemistry HL Paper 3 Markscheme

General

- Each marking point has a separate line and the end is signified by means of a semicolon (;).
- Alternative answers are separated by a slash (/) – this means that either answer is acceptable.
- Words underlined are essential for the mark.
- Material in brackets (…) is not needed for the mark.
- The order in which candidates score marks does not matter (unless stated otherwise).
- The use of ***OWTTE*** in a markscheme (the abbreviation for "or words to that effect") means that if a candidate's answer contains words different to those in the markscheme, but which can be interpreted as having the same meaning, then the mark should be awarded.
- Please remember that many candidates are writing in a second language, and that effective communication is more important than grammatical accuracy.
- In some cases there may be more acceptable ways of scoring marks than the total mark for the question part. In these cases, tick each correct point, and if the total number of ticks is greater than the maximum possible total then write the maximum total followed by **MAX**.
- In some questions an answer to a question part has to be used in later parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in later parts then "follow through" marks can be scored. Show this by writing **ECF** (error carried forward). This situation often occurs in calculations but may do so in other questions.
- Units for quantities should always be given where appropriate. In some cases a mark is available in the markscheme for writing the correct unit. In other cases the markscheme may state that units are to be ignored. Where this is not the case, penalize the omission of units, or the use of incorrect units, once only in the paper, and show this by writing **–1(U)** at the first point at which it occurs.
- Do not penalize candidates for using too many significant figures in answers to calculations, unless the question specifically states the number of significant figures required. If a candidate gives an answer to fewer significant figures than the answer shown in the markscheme, penalize this once only in the paper, and show this by writing **–1(SF)** at the first point at which this occurs.
- If a question specifically asks for the name of a substance, do not award a mark for a correct formula; similarly, if the formula is specifically asked for, do not award a mark for a correct name.
- If a question asks for an equation for a reaction, a balanced symbol equation is usually expected. Do not award a mark for a word equation or an unbalanced equation unless the question specifically asks for this. In some cases, where more complicated equations are to be written, more than one mark may be available for an equation – in these cases follow the instructions in the mark scheme.
- Ignore missing or incorrect state symbols in an equation unless these are specifically asked for in the question.
- Mark positively. Give candidates credit for what they have got correct, rather than penalizing them for what they have got wrong.
- If candidates answer a question correctly, but by using a method different from that shown in the markscheme, then award marks; if in doubt consult your Team Leader

Option B – Medicines and drugs

B1. (a) *mild analgesic*
intercepts pain at the source / *OWTTE*;
by interfering with the production of substances that cause pain/prostaglandins / *OWTTE*;
Accept enzymes but not hormones.

strong analgesic
binds to pain receptors in the brain;
preventing the transmission of nerve impulses; ***[4]***

(b) (i) *advantage*
prevents inflammation / thins blood / effective against blood clots / prevents strokes / quick acting / prevents the recurrence of heart attacks / relieves symptoms of arthritis/rheumatism / reduces fever;

disadvantage
irritates the stomach lining / produces allergic reactions / Reye's syndrome / causes stomach bleeding / causes stomach ulcers; ***[2]***

(ii) increases the risk of stomach bleeding/haemorrhage / enhances depression of CNS; ***[1]***

(iii) may cause kidney/liver damage; ***[1]***

B2. (a) narrow spectrum effective only against certain types of bacteria whereas broad spectrum effective against a wider range of bacteria; ***[1]***
There must be some reference to different types of bacteria.

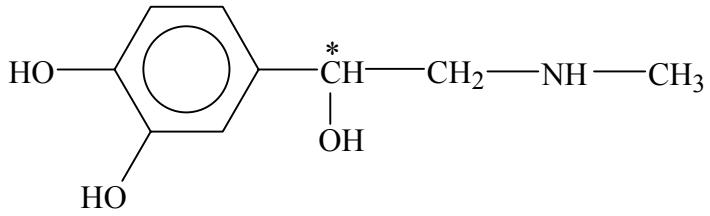
(b) penicillins prevent bacteria from manufacturing cell walls;
develop new penicillins to overcome the resistance that bacteria develop to existing antibiotics / *OWTTE*; ***[2]***

(c) increases resistance to the penicillinase enzyme / alters shape/stability/solubility; ***[1]***

(d) (i) makes penicillins less effective;
destroys useful/good bacteria;
allows resistant population to build up; ***[3]***

(ii) use of penicillins in animal feeds / people not completing their course of penicillin; ***[1]***

B3. (a) *[1]*



(b) a chiral auxiliary is an optically-active species;
that can be connected to a molecule (to make it optically-active);
when this species is reacted further (then removed) only one enantiomer results;
eliminates the need to carry out the separation of the desired enantiomer from a racemic mixture; *[4]*

B4. (a) cause changes in visual and sound perception / hallucinations;

LSD may cause a permanent effect of 'flashbacks'/effects of LSD may be experienced a year or more after the last use of the drug / psychological dependence; *[2]*

OR

mescaline may cause nausea / trembling / liver damage / reduce appetite ;

(b) both contain amines / aromatic (benzene) ring;

mescaline	*LSD*
primary amine	secondary and tertiary amine
ether groups	amide
one ring	alkene(s)
	indole ring
	four cyclic rings
	heterocyclic

Accept any one clear difference from the above list. *[2]*

Option C – Human biochemistry

C1. (a) saturated fats have only single C—C bonds / unsaturated fats have C═C bonds; ***[1]***
Do not accept references to double or single bonds without mention of carbon, comparison must be implied.

(b) palmitic acid is saturated / linoleic acid is unsaturated / *OWTTE*;

palmitic acid chains are straighter / linoleic acid chains are more kinked / *OWTTE*;

palmitic acid chains can pack more closely / linoleic acid chains can pack less closely / *OWTTE*;

palmitic acid has stronger van der Waals' forces / linoleic acid has weaker van der Waals' forces; ***[3 max]***
Accept intermolecular forces but not hydrogen bonding.

(c) heat released by oil = mass of water × specific heat of water × change in temperature / $q = mc\Delta t$;
$= 1000 \times 4.18 \times 47.3$;
(*mark is for correct temperature change*)
No penalty for 4.2 instead of 4.18.

calorific value $= \frac{1000 \times 4.18 \times 47.3}{5.00\ \text{g}}$;
$= 39.5$ to $40\ (\text{kJ g}^{-1})$; ***[4]***
*Award **[4]** for correct final answer.*

C2. vitamin C is water soluble and vitamin A/D is fat soluble;

vitamin C has 4/several OH groups / vitamin A/D has only 1/fewer OH groups;

vitamin A/D has large non-polar/hydrocarbon part/chain/ring;

vitamin C has hydrogen bonding and vitamin A/D has van der Waals' forces; ***[4]***

C3. *benefits* ***[2 max]***
improve food productivity / provide more food;
(food) crops are more resistant to disease / more resistant to insect attack / more tolerant to toxins;

improve aesthetics / composition of some foods;
improved flavour;
improved texture;
improved nutritional value;
improved shelf life;

incorporation of anti-cancer substances / vaccines / reduce exposure to less healthy fats;

concerns ***[2 max]***
contaminate normal DNA in crops/animals / alter eco-systems / long-term effect unknown / may increase risk of disease; ***[4 max]***
Award ***[1]*** *each for any two*.

C4. (a) catalyse/speed up chemical reactions (in the body) / make reactions possible at body temperature / lower activation energy. ***[1]***

(b) $V_{max} = 0.46\ \mu mol\ min^{-1}$;
$K_m = [S]$ when $v = ½\ V_{max} = 1.2\ mmol\ dm^{-3}$; ***[2]***
Accept 1.1 - 1.3 mmol dm^{-3}.
Penalize once for wrong / no units.

(c) rate increases due to more frequent collisions;
rate of increase slows due to occupancy of active site on enzyme;
V_{max} occurs when all active sites are occupied/saturated; ***[3]***

(d) a flatter line which begins at the origin and takes longer to reach V_{max}; ***[1]***

C5. heme / haem / hemoglobin;
+2; ***[2]***

Option D – Environmental chemistry

D1. (a) *Any two of the following*: CH_4, H_2O, CO_2, N_2O, O_3, CFCs, SF_6; ***[1]***

Accept names instead of formulas.
Do not accept NO_x or other oxides of nitrogen.
If any incorrect gas is given award zero.

(b) Earth radiates infrared radiation / long wavelength radiation;
gas molecules absorb radiation / bonds (in gas molecules) vibrate more;
(re-)radiated back to the Earth's surface; ***[3]***

D2. (a) chlorofluorocarbons / CFCs ;
Accept correctly named examples.

from refrigerants / propellants for aerosols / fire extinguishers / foaming agents / cleaning solvents / coolant / air-conditioning systems;

OR

oxides of nitrogen / NO_X ;
(from) internal combustion engine / power stations / jet aeroplanes; ***[2 max]***

(b) *advantage*
does not produce $Cl\bullet$ / no weak C—Cl bonds / stable / has same properties as CFCs / no (free) radicals formed / hydrofluorocarbons have shorter (atmospheric) lifetime;

disadvantage
greenhouse gas / global warming / hydrofluorocarbons are flammable; ***[2]***

D3. (a) *primary stage*
filtration / flocculation / sedimentation / settling tank / screening / grids;

substance removed
solids / insoluble material / oxygen-demanding wastes;

secondary stage
activated sludge process / use of bacteria and oxygen / trickle filter;

substances removed
organic wastes / oxygen-demanding wastes; ***[4]***

(b) organic material;
carbon bed;

heavy metals;
chemical precipitation / description of reaction;

phosphates;
chemical precipitation / description of reaction;
Penalize missing "chemical" once only.

nitrates;
ion exchange / algal ponds / denitrifying bacteria; ***[4 max]***
*Award **[1]** each for any two materials removed and award **[1]** each for two explanations corresponding to the stated materials removed.*

D4. *primary pollutants*
hydrocarbons / nitrogen oxides / NO_X;

secondary pollutants
ozone / ketones / aldehydes / peroxyacyl nitrates (PANs) / peroxides / nitric acid;

sunlight causes the formation of free-radicals which lead to secondary pollutants / suitable equation involving free radicals;

e.g. $NO_2 \rightarrow NO + O\bullet$
$O\bullet + H_2O \rightarrow 2OH\bullet$
$OH\bullet + NO_2 \rightarrow HNO_3$
$OH\bullet + RH \rightarrow R\bullet + H_2O$
$R\bullet + O_2 \rightarrow ROO\bullet$
$RCOOO\bullet + NO_2 \rightarrow RCOOONO_2$

thermal inversion traps the polluted air closer to the ground; ***[4]***

D5. *cadmium source*:
metal plating / some rechargeable batteries / orange pigments / zinc refining;

environmental effect:
toxic to fish / birth defects in mice / induces abortions in some animals;

human health effect:
Itai-Itai disease / lung/kidney cancer / vomiting / stomach pains / diarrhoa;

OR

mercury source:
mercury cell (chlor-alkali industry) / batteries / Hg amalgams for dental fillings /
Hg salts as fungicides / seed dressing;

environmental effect:
inhibits growth and kills fish / causes fish reproductive systems to fail;

human health effect:
Minamata disease / paralysis / mental disorders / damage to liver/kidney;

OR

lead source:
lead paints / tetraethyl lead petrol (gasoline) / lead water pipes / car batteries;

environmental effect:
toxic to plants / toxic to animals;

human health effect:
brain damage / still births / low birth mass / hypertension / kidney failure / abdominal pains; ***[3 max]***

D6. large doses may be required to kill 50 % of the population;
different species react differently to different toxins / *OWTTE*;
international LD_{50} for all toxic substances not uniform / LD_{50} for a particular toxic substance may vary from country to country; ***[2 max]***
*Award **[1]** each for any two*.

Option E – Chemical industries

E1. (a) *isotactic*
methyl groups have the same orientation along the polymer;

atactic
methyl groups are arranged randomly along the polymer; ***[2]***
*Award **[2]** for suitable diagrams*.

(b) crystalline;
tough;
high tensile strength;
hard / stiff;
can be moulded;
can be drawn into fibres;
*Award **[1]** for any two*.

regular packing / strong(er) forces between chains; ***[2 max]***
Accept crystalline as either property or structure, but not both.

E2. (a) reduction / redox; ***[1]***

(b) position of metal in reactivity/electrochemical series;
Al is higher in the series so harder to extract / Fe is lower in the series so easier to extract; ***[2]***

E3. (a) haematite **and** Fe_2O_3; ***[1]***
*Accept magnetite **and** Fe_3O_4.*

(b) (i) silicon (IV) oxide **and** SiO_2; ***[1]***
Accept silica and silicon dioxide, but not silicon oxide.

(ii) limestone;
Do not accept lime or calcium carbonate.
$CaCO_3 \rightarrow CaO + CO_2$ **and** $CaO + SiO_2 \rightarrow CaSiO_3$ / $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$; ***[2]***

(c) electrolysis;

EITHER

$2O^{2-} \rightarrow O_2 + 4e^-$;
$Al^{3+} + 3e^- \rightarrow Al$;

OR

$2Al_2O_3 \rightarrow 4Al + 3O_2$;
$C + O_2 \rightarrow CO_2$; ***[3]***

(d) cryolite is a flux/solvent
reduces operating temperature / lowers the melting point of Al_2O_3;
less energy is required for the production of aluminium; ***[2]***
*Any of the above award **[1]** each.*

E4. (i) $2Cl^- \rightarrow Cl_2 + 2e^-$;
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ / $2H^+ + 2e^- \rightarrow H_2$ / $Na^+ + e + Hg \rightarrow Na/Hg$ (sodium amalgam); ***[2]***
Electrodes do not need to be indicated, but deduct ***[1]*** *if equations linked to incorrect electrodes*.

(ii) *Any two from*:
(asbestos) diaphragm / mercury electrode/cathode / ion exchange membrane; ***[1]***

(iii) hydrogen **and** manufacture of ammonia / margarine / use as fuel;
sodium hydroxide **and** manufacture of soap / detergents / polyesters (e.g. rayon) / bleaches; ***[2]***
Accept other valid industrial uses.

E5. *n-type semiconductors*
a group 5 element (*e.g.* As, P) is added;
it provides extra electrons;

p-type semiconductors
a group 3 element (*e.g.* In, Ga, Al) is added;
this creates electron holes; ***[4]***

Option F – Fuels and energy

F1. (a) (i) *advantage*
can obtain a large fraction of the energy available / more efficient / ease of use / biomass is renewable;
disadvantage
may cause a lot of pollution / expensive to transport / cannot replace liquid fuels; ***[2]***

(ii) *advantage*
liquid fuel has more uses (*e.g.* motor vehicles) / burns more cleanly;
disadvantage
less energy is available from ethanol than from raw plants / time needed for conversion; ***[2]***
Do not accept both an advantage and a converse disadvantage.

(b) *advantage*
renewable source of energy / no pollution / can be used continuously / in remote locations / low maintenance / no moving parts;
disadvantage
solar cells are expensive to produce / may not be effective in areas where there is little sunshine / inefficient energy conversion; ***[2]***

F2. (a) (i) one electrode is made of Pb;
the other electrode is made of PbO_2;
Accept lead (IV) oxide and lead dioxide.
electrolyte is H_2SO_4;
$Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$;
$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$; ***[5]***
Accept reversed equations.

(ii) oxidation;
electrons are released / oxidation number of Pb increases;
If reduction given, second mark cannot be scored. ***[2]***

(b) (i) number of cells connected together (in series) / concentration of acid / temperature; ***[1]***

(ii) size of the electrodes / amount of material; ***[1]***

F3. (a) β (beta minus) decay;
the n:p ratio (18:15) is greater than that in stable P-31 (16:15) / more n than p; ***[2]***
Do not accept too many neutrons / OWTTE.

(b) (i) $\left(\frac{0.693}{t_{1/2}} = k\right)$ $k = 0.0277$ / $\frac{\ln 2}{25}$ day^{-1};

(ii) $\ln\frac{A_o}{A} = 0.0277\ day^{-1} \times 7\ days$ / $\ln\frac{A_o}{A} = 0.194$ / $\frac{A_o}{A} = 1.214$ / $\frac{A}{A_o} = 0.824$;
$1 - 0.824 = 0.176$ / 17.6% (fraction decayed); ***[3]***
*Award **[2]** for correct final answer. Award **[1 max]** for 82.4%.*
Do not penalize for significant figures.

F4. (a) is the energy required to break a nucleus into separate protons and neutrons / the energy given out when a nucleus is formed from separate protons and neutrons; ***[1]***

(b) the most stable nuclei have a mass number between 50 and 60;
as small nuclei/lower BEPNs are converted to heavier ones/higher BEPNs, energy is released;
heavier nuclei/lower BEPNs are converted to lighter ones/higher BEPNs (fission);
the curve ends because there are no stable nuclei with mass numbers > 240; ***[4]***

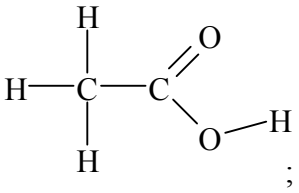
Option G – Modern analytical chemistry

G1. (a) A is the ultraviolet / UV;
electronic transitions;
B is the infrared / IR;
molecular vibrations;
A is higher energy than B / *OWTTE*; ***[5]***
If A and B the wrong way round ***[3 max]***.

(b) (i) A (because) electron transitions occur; ***[1]***

(ii) B from vibration frequencies; ***[1]***
Allow ECF from (a).

G2. (a)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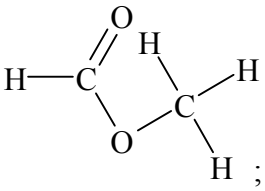
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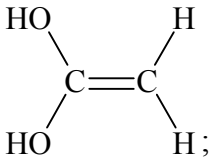
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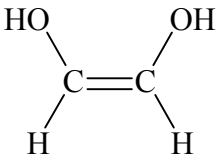
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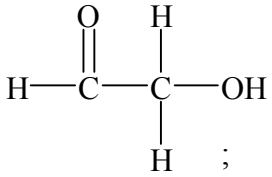
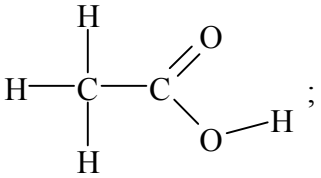

;

[2]

Accept correct cyclic isomers.
If no H atoms shown ***[1 max]***.

(b) 2920 cm^{-1} C—H;
2765 cm^{-1} O—H (in hydrogen bonded acids);
1710 cm^{-1} C═O ; ***[2 max]***
Award ***[2]*** *for three correct,* ***[1]*** *for two correct.*

(c)


;

(because of) the position of O—H vibration; ***[2]***

G3. (a) (i) the number of different <u>hydrogen/proton</u> environments / *OWTTE*; ***[1]***

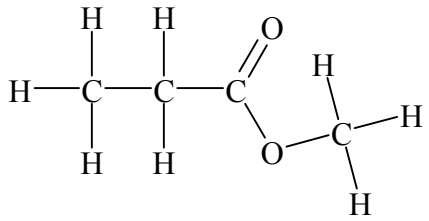
(ii) the environment of proton / neighbouring group / *OWTTE*; ***[1]***

(iii) the ratio of the numbers of protons <u>in each environment</u>; ***[1]***

(iv) the number of (identical) protons on the neighbouring carbon atom(s); ***[1]***

(b) 0.9 ppm H on C attached to a second C / alkyl group / R—CH_3
2.0 ppm H on C attached to carboxyl C / C of an ester / CH_3—CO—OR
4.1 ppm H on C attached to O of carboxyl group / ester group / R—CO—OCH_2R ***[3]***

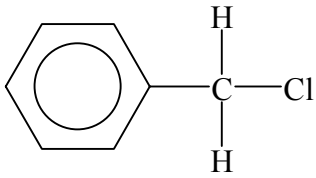
(c) *Structure* ***[2]***



Explanation ***[3 max]***
two CH_3 groups in different environments;
one CH_3 group is not next to a C / has no neighbouring protons;
because it is a singlet (at 4.1ppm);
CH_2 next to CH_3 / C_2H_5;
because of triplet and quartet; ***[5 max]***
Award ***[2]*** *for correct structure,* ***[3]*** *for any three correct points for explanation.*
Award ***[3 max]*** *if structure* $CH_3COOCH_2CH_3$.

Option H – Further Organic Chemistry

H1. (a)

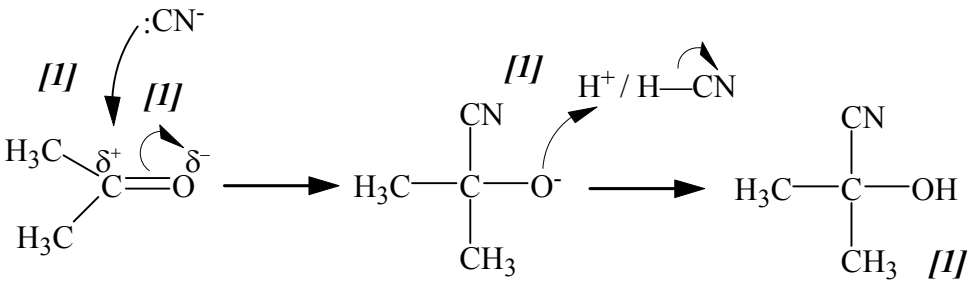


[1]

(b) $Cl_2 \rightarrow 2Cl\bullet$ initiation;
$Cl\bullet + C_6H_5CH_3 \rightarrow C_6H_5CH_2\bullet + HCl$ propagation;
$C_6H_5CH_2\bullet + Cl_2 \rightarrow C_6H_5CH_2Cl + Cl\bullet$ propagation;
any correct termination equation termination *[5]*
*Award **[1]** for each correct equation. Award **[1]** for correct naming throughout. Ignore "curly arrows".*

(c) breaks Cl—Cl bond homolytically / produce free radicals; *[1]*

H2. (a)



Suitable diagram with
curly arrow showing attack by CN^- on carbonyl $C^{\delta+}$;
curly arrow showing pi bond breaking;
curly arrow from O to H^+ / H—CN;
structure of product $(CH_3)_2C(OH)CN$; *[4]*
Accept more detailed formula.

(b) $(CH_3)_2C(CN)OH + H^+ + H_2O \rightarrow (CH_3)_2C(COOH)OH + NH_4^+$;
carboxylic acid **and** alcohol; *[2]*
Accept hydroxy(l) instead of alcohol.