M09/4/CHEMI/SP3/ENG/TZ2/XX/M+

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MARKSCHEME

May 2009

CHEMISTRY

Standard Level

Paper 3

19 pages

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Subject Details: Chemistry SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the options **[2 × 20 marks]**. Maximum total = **[40 marks]**

1. A markscheme often has more marking points than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/) - either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are underlined are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. Indicate this with **ECF** (error carried forward).

10. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover page.

11. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

Indicate the mark deduction by writing **–1(SD)** at the first point it occurs and **SD** on the cover page.

12. 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.

13. 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 directed otherwise in the markscheme.

14. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

Option A — Modern analytical chemistry

A1. (a) absorption spectrum: energy required to move/excite (electrons) from lower/ground state to higher energy level/excited state;

emission spectrum: radiation emitted by electrons from higher/excited state to lower/ground energy level;

OR

absorption spectrum: continuous spectrum with missing regions/lines corresponding to energies absorbed;

emission spectrum: regions/lines corresponding to energies given out/emitted; ***[2]***

(b) (i) (^{1}H/proton) NMR/nuclear magnetic resonance; ***[1]***

(ii) AA(S)/atomic absorption; ***[1]***

(c) (i) stationary phase is a thin layer of SiO_2/silica/silicon dioxide/ Al_2O_3/alumina/ aluminium oxide (on support) (and mobile phase a solvent);
Ignore reference to H_2O in stationary phase.

distance travelled/separation (of components) depends on adsorption/bonding to stationary phase / polarity of component / relative solubility between two phases; ***[2]***
No mark for absorption.

(ii) separation is better/more effective/faster/efficient / separated component can be more easily recovered / withstands strong solvents / develops better; ***[1]***

(iii) $R_f = \frac{40\,(\text{mm})}{46\,(\text{mm})} = 0.87$; ***[1]***
Allow 0.86 to 0.88.
No mark if R_f has units.

A2. (a) $C_2H_4O_2$; ***[1]***
No mark for $(CH_2O)_2$.

(b) *m/z = 15*
CH_3^+;

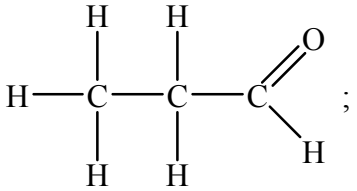
m/z = 45
$COOH^+/CO_2H^+/HCOO^+/OCOH^+$; ***[2]***
Penalize once if charges are missing.

(c) ethanoic acid/ CH_3COOH / methyl methanoate/ $HCOOCH_3$; ***[1]***
Accept acetic acid.

A3. (a) infrared: vibrations (stretching and bending) of bonds increase;
visible light: electronic transitions to higher energy levels / electrons excited to higher energy levels; ***[2]***

(b) O_2 is non-polar/has no dipole moment/symmetrical;
the stretching of the O=O bond would not change the polarity/dipole moment; ***[2]***

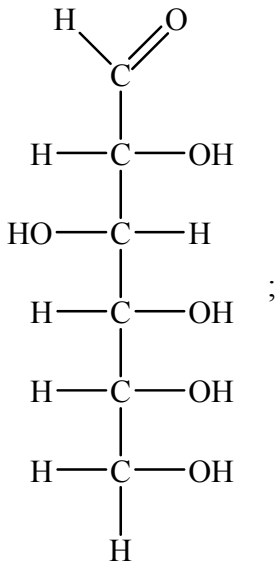
(c) (i) absence of peak between 3200–3600 cm^{-1}/above 3000 cm^{-1}/peak for OH;
presence of peak between 1700–1750 cm^{-1}/peak for C=O;
absence of peak between 1610–1680 cm^{-1} /peak for C=C; ***[2 max]***

(ii) 

;
Accept CH_3CH_2CHO.

3:2:1; ***[2]***
Ignore order
ECF if structure is incorrect only if its NMR spectrum contains three peaks.

Option B — Human biochemistry

B1. (a) 

;

[1]

Accept CHO, CH_2OH and OH groups on either side of the carbon chain provided OH on C3 is on the opposite side to OHs on C2, C4 and C5.

(b) C1 is asymmetric/chiral/has four different groups;
forming two isomers where the OH-group is on a different side (of C1/ring);
α-glucose **and** β-glucose; ***[3]***
Accept suitable diagrams as an explanation for M2.

(c) amylose **and** amylopectin; ***[1]***

(d) amylose: α-1,4 **and** linear/straight chain;
amylopectin: α-1,4 **and** α-1,6 **and** branched; ***[2]***
*Award **[1]** if both linkages or both structures are correct.*

B2. (a) steroid/steroidal backbone/4 ring/tetra cyclic carbon structure skeleton; ***[1]***
Do not accept OH, hydroxyl, hydroxide, alcohol.
Accept a correct sketch of the steroid backbone.

(b) phospholipids;
triglycerides/triglycerols; ***[2]***

(c) (i) high density lipoprotein **and** low density lipoprotein; ***[1]***

(ii) HDL has a higher proportion/percentage of proteins/LDL has a lower proportion of proteins / *OWTTE*; ***[1]***

(d) both have 18 carbon atoms;
both have carboxyl/COOH;
linoleic acid has 2 double bonds **and** linolenic 3 / linoleic acid has less double bonds / linoleic acid is less unsaturated;
first double bond of linoleic is after the 6^{th} C atom **and** first of linolenic is after the 3^{rd} C atom from the end of the CH_3 group/counting from side of the chain that does not have COOH group / linoleic acid is omega-6 **and** linolenic acid is omega-3 / *OWTTE*; ***[3 max]***

B3. (a) vitamin A: not water-soluble because it has only one OH / is not very/less polar / contains long hydrocarbon group;
vitamin C: water-soluble because it has 4/many OH (and 1 C=O)/extensive hydrogen bonding; ***[2]***
Accept reference to polarity in one case but not in both.

(b) effect: vitamin A: xerophthalmia/night blindness / vitamin C: scurvy / bleeding gums / less resistance to infection / bleeding lesions on legs/thighs / scorbutus;

Accept either of the following for the second mark:
solution for vitamin A: providing food composed of liver/fresh (orange and green) fruits/vegetables/spinach/eggs/carrots / providing genetically modified food containing vitamin A;

OR

solution for vitamin C: providing food composed of fresh fruits/vegetables/ providing genetically modified food containing vitamin C;

providing nutritional supplements / adding vitamin A/C in commonly consumed foods / vitamin A in margarine / vitamin C in fruit juices; ***[3 max]***

Option C — Chemistry in industry and technology

C1. (a) homogeneous mixture of metals/a metal and non-metal; ***[1]***

(b) alloying element(s) disrupts regular/repeating (metal) lattice;
difficult for one layer to slide over another / atoms smaller than the metal cations can fit into the (holes of) metal lattice disrupting bonding;
can make metal harder/stronger/more corrosion resistant/brittle; ***[2 max]***

(c) makes steel less brittle/softer/more ductile; ***[1]***

(d) Fe and Al production use large quantities of energy / about ten times/much more energy needed to produce Al than (similar mass of) Fe;
(mined) areas can leave scars on landscape (unless mining companies re-vegetate areas) / destroys animal/plant habitat;
(mining) waste products/tailings/metal wastes can damage environment / purification of bauxite produces considerable waste of iron(III) oxide which can result in visual pollution;
(large volume of) CO_2 produced which contributes to global warming; ***[2 max]***

C2. *Mode of action of homogeneous catalysis*:
catalyst reacts in one step (of the mechanism) and is regenerated at a later step / ability to form a range of oxidation states (for transition metals) / reaction steps with catalyst have lower activation energies than for reaction without catalyst / *OWTTE*;

Example using chemical equation:
$CH_3COOH(aq) + C_2H_5OH(aq) \rightleftharpoons^{H^+(aq)} CH_3COOC_2H_5(aq) + H_2O(l)$ / other suitable example;

Mode of action of heterogeneous catalysis:
catalyst provides the reactive surface / presence of active sites / adsorb reactant molecule(s) (on surface);

Example using chemical equation:
$2SO_2(g) + O_2(g) \rightleftharpoons^{V_2O_5(g)} 2SO_3(g)$ / $N_2(g) + 3H_2(g) \rightleftharpoons^{Fe(s)} 2NH_3(g)$ /
$C_2H_4(g) + H_2(g) \rightleftharpoons^{Ni(s)} C_2H_6(g)$ / other suitable example; ***[4]***
Reversible sign not required for mark.
Catalyst and states must be specified to score mark.

C3. (a) contains no lithium/metal / uses lithium salt in an organic solvent (as electrolyte);
involves movement of lithium ions (between electrodes); ***[2]***

(b) *Anode (–)*:
$LiC_6 \rightarrow Li^+ + 6C + e^-$ / Li^+ ions dissociate from anode (and migrate to cathode);

Cathode (+):
$Li^+ + e^- + MnO_2 \rightarrow LiMnO_2$ / $Li^+ + e^- + CoO_2 \rightarrow LiCoO_2$ / $Li^+ + e^- + FePO_4 \rightarrow LiFePO_4$ /
$Li^+ + e^- + NiO_2 \rightarrow LiNiO_2$ / Li^+ ions are inserted into metal oxide/phosphate (structure); ***[2]***
*Award **[1]** if electrodes are reversed.*

(c) *Similarity*:
both convert chemical energy directly into electrical energy / both use spontaneous redox reactions (to produce energy) / both are electrochemical cells/voltaic cells/galvanic cells;

Difference:
fuel cells are energy conversion devices **and** rechargeable batteries are energy storage devices / fuel cells require constant supply of reactants **and** batteries have stored chemical energy/provide power until stored chemicals are used up / batteries can be recharged **and** fuel cells do not need recharging (have a continuous supply of fuel) / fuel cells are more expensive than rechargeable batteries / the reactions in a rechargeable battery are reversible **and** in a fuel cell are not; ***[2]***

C4. (a)

	Crystalline solid	**Nematic phase liquid crystal**	**Pure liquid**	
Positional order	yes	no	no	;
Directional order	yes	yes	no	; ***[2]***

Need all three across table for each mark.

(b) liquid crystal molecules work over a limited temperature range;
ability of liquid crystal molecules to transmit light depends on molecular orientation / *OWTTE*;
orientation of polar molecules controlled by applying voltage across a small section;
areas of the material/display that are dark and light can be controlled; ***[2 max]***

Option D — Medicines and drugs

D1. measure of the relative margin of safety of a drug (for a particular treatment for a typical population) / measure for safe effective treatment;

$$\frac{\text{lethal dose } (LD_{50})}{\text{therapeutic or effective dose } (ED_{50})} \text{ /}$$

ratio of the lethal dose (LD_{50}) to the therapeutic or effective dose (ED_{50}) / the range of dosage of a drug/its concentration in a bodily system/blood;
Definition of LD_{50} and ED_{50} not required for mark.

wide therapeutic window exists for small effective dose and larger lethal dose / toxicity occurs at much higher concentrations than for successful treatment / a big difference between effective and lethal dose / drugs with wide therapeutic window are safer;
narrow therapeutic window requires small doses as lethal dose is not large / *OWTTE*; ***[4]***

D2. (a) $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$ / $HCO_3^- + H^+ \rightarrow H_2O + CO_2$; ***[1]***
States not required for mark.

(b) $CaCO_3$;
1 mol $NaHCO_3$ neutralizes 1 mol HCl **and** 1 mol $CaCO_3$ neutralizes 2 mol HCl /
$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$; ***[2]***

D3. (a) (i) *Oxidation*:
$C_2H_5OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$;

Reduction:
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$; ***[2]***
Accept balanced equation with molecular formulas.
*If both equations are wrong, award **[1]** for $C_2H_5OH \rightarrow CH_3COOH$ and $Cr_2O_7^{2-} \rightarrow 2Cr^{3+}$.*
*If correct equations are used but oxidation and reduction reversed, award **[1]**.*

(ii) orange to green; ***[1]***

(b) peak at $2950\ cm^{-1}$ / absorption occurs due to C–H bonds in ethanol;
No mark for absorption due to just ethanol, or O–H bond in ethanol (water vapour in breath also contributes).

intensity / height of peak / absorption / amount of transmittance depends on amount of ethanol / compare absorption to standard / reference/control sample / sample containing no alcohol; ***[2]***

D4. (a) side chain/alkyl group;
Accept hydrocarbon chain.

modify side chain / use different R groups; ***[2]***
Ignore reference to functional groups.

(b) may wipe-out helpful/useful/beneficial bacteria (in the alimentary canal);
destroyed bacteria may be replaced by more harmful bacteria;
leads to resistance / makes penicillin less effective;
resistant bacteria grow / pass on their immunity/mutation/trait to succeeding generations / *OWTTE*; ***[2 max]***

D5. HIV invades/bind to white blood cells/T4/T cells / *OWTTE*;
HIV viruses can mutate;
HIV viruses have similar metabolism to (human) cells/uses host cells to replicate;
high price of (antiretroviral) drugs / socioeconomic / cultural issues; ***[4]***

Option E — Environmental chemistry

E1. (a) *NO*:
N_2 and O_2 react in the engine / $N_2 + O_2 \rightarrow 2NO$;
No mark for the high temperature without reference to the action between N_2 and O_2.

NO_2:
NO oxidizes/reacts in the air to NO_2 / $2NO + O_2 \rightarrow 2NO_2$;

CO:
incomplete combustion; ***[3]***
Accept balanced chemical equation for C5–C12 hydrocarbons.
Do not accept C1–C4.

(b) combustion is incomplete therefore more CO is produced;
more VOCs remain unreacted;
(lack of air) reduces [NO]; ***[3]***
*Allow **[1 max]** if all correct answers correspond to air/fuel ratio.*

E2. (a) refrigerants / air conditioners / spray cans / fire extinguishers / aerosols / solvents / foaming agents; ***[1]***

(b) can be liquefied at room temperature;
low toxicity;
low flammability;
lack of reactivity; ***[2 max]***
Do not accept less expensive or better refrigerants.

(c) advantage: stable/strong C–F bonds / low reactivity / not flammable / no Cl present / no ozone depletion;
disadvantage: greenhouse gas / contributes to global warming; ***[2]***

E3. (a) (i) decayed plant and animal tissue/matter / soil biomass / non-living organic components / *OWTTE*; ***[1]***
No mark for humus (question asks for main constituent of SOM).

(ii) *Provision of nutrients*:
contains N/amine/amino acid / H (of COOH) can be interchanged by ions of nutrients / ion exchange of nutrients can occur due to H (of COOH);

Water retention:
has (polar) OH/NH;
these can form hydrogen bonds (with water molecules in the soil); ***[3]***

(b) irrigation waters contain salts;
upon evaporation these stay (causing salinization of the soil);
plants do not grow on soil with high salt content;
over irrigation/water run off can remove nutrients/ Ca^{2+}/K^{+}/NH_4^{+}/Mg^{2+}; ***[3 max]***

(c) *Polyaromatic hydrocarbons (PAHs)*:
tar / coal / crude oil spills / incomplete combustion of wood/vegetation/waste / industrial/power station emissions;
Do not accept hydrocarbons.

Organotin compounds:
PVCs with tin compounds / antifouling compounds (coatings or paints) / fungicides / pesticides / biocidal agents; ***[2]***

Option F — Food chemistry

F1. (a) ester of glycerol/propan-1,2,3-triol **and** three fatty acids/long chain carboxylic acids; ***[1]***

(b) II;
more straight molecule/greater surface area hence greater distortion of electron cloud / allows closer packing of fatty acids for trans / does not allow closer packing for cis isomers / *OWTTE*;
trans greater van der Waals' forces / cis less van der Waals' forces; ***[3]***
Accept London/dispersion forces.

(c) advantages ***[2 max]***:
changes liquid into semi-solid / increases hardness;
products are more stable;
oxidize less easy;

disadvantages ***[2 max]***:
increase the level of LDL cholesterol / increase risks of artheriosclerosis/ arteriosclerosis/cardiovascular diseases;
trans fats are less easy to digest / are difficult to metabolize;
accumulate in body tissue; ***[4 max]***

F2. (a) protein;
fat/lipid; ***[2]***
Do not accept water.

(b) excludes oxygen/air;
prevents oxidation;
avoids decomposition with aerobic bacteria/fungi; ***[2 max]***
Do not accept excludes light.

(c) (i) preserves meat / cures meat / fixes colour / inhibits microorganisms; ***[1]***

(ii) antioxidant; ***[1]***

F3. (a) purplish-red colour of meat is produced by myoglobin;
Accept heme.

Fe has oxidation state +2 in myoglobin;
(upon standing) oxidizes to Fe^{3+} which is brown; ***[3]***

(b) food pigments have a system of conjugated double bonds/delocalized electrons;
absorb light of certain frequency in the visible region / of certain colours;
reflected/transmitted light has (complementary) colour; ***[3]***

Option G — Further organic chemistry

G1. (a) bonding electron pair spread over three (or more) nuclei or atoms/not restricted/ confined between two nuclei or atoms / *OWTTE*; ***[1]***

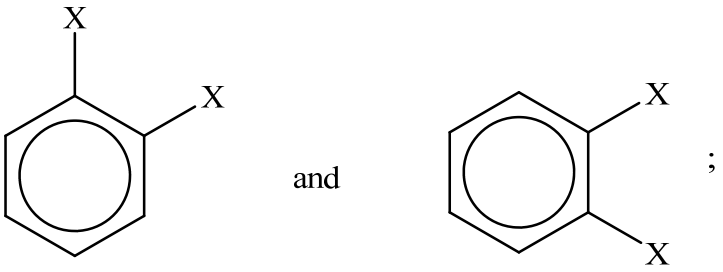
(b) physical evidence ***[2 marks]***:

same carbon–carbon bond lengths in benzene / all carbon–carbon bonds are equal in length / forms regular hexagon;
instead of longer single bonds **and** shorter double bonds / intermediate between single and double;

OR

3 isomers of $C_6H_4X_2$;
not 4;

OR



;

not (structural) isomers / same compounds;

OR

(^{1}H/proton) NMR spectrum shows only one peak / all the Hs in the same chemical environment;
not 2 peaks / not 2 different chemical environments;

OR

electron density maps;
show even electron density over ring;

chemical evidence ***[2 marks]***:

hydrogenation of C_6H_6 (1,3,5-cyclohexatriene) expected to produce three times as much energy as cyclohexene;
benzene produces less (due to delocalization);

OR

benzene undergoes substitution rather than addition reactions;
as it is more stable (due to delocalization);

OR

enthalpy of combustion of C_6H_6 less than expected;
different bond energies; ***[4 max]***

(c) reaction is faster with $C_6H_5CH_2Cl$;
C–Cl bond weaker/easier to break;
because no overlap between a lone electron pair of Cl with ring delocalized electrons;
attacking OH^- nucleophile not repelled by the delocalized electrons;

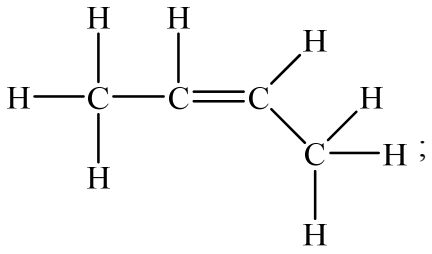
OR

reaction is slower with C_6H_5Cl;
C–Cl bond stronger/harder to break;
because of overlap between a lone electron pair of Cl with ring delocalized electrons / delocalization increases electron density on ring / delocalization reduces δ+ charge on C (attached to Cl atom);
attacking OH^- nucleophile repelled by delocalized electrons / attraction of nucleophile decreases / less polar C does not attract OH^- as much; ***[3 max]***

G2. major product:
$(CH_3)_2CBrCH_2CH_3$/2-bromo-2-methylbutane;

minor product:
$(CH_3)_2CHCHBrCH_3$/2-bromo-3-methylbutane;
mention of carbocation/$(CH_3)_2C^+CH_2CH_3$/$(CH_3)_2CHCH^+CH_3$;
tertiary more stable than secondary carbocation / more alkyl groups with positive inductive effect;
more <u>electron releasing/pushing</u> R/alkyl/C groups in tertiary; ***[5]***

G3.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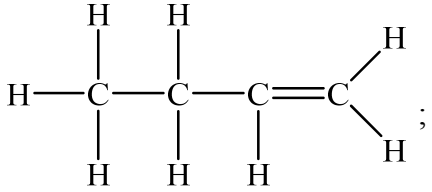
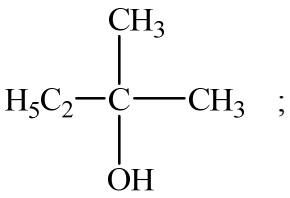

;

[2]

Accept condensed structural formulas

G4. (a) reaction of Mg/magnesium with halogenoalkane/named compound;
in an anhydrous/dry solvent / $(C_2H_5)_2O$ /diethyl ether; ***[2]***
Accept equation with condition specified.

(b) 

;

Accept either of the two following alternatives for the second and third mark.

CH_3COCH_3 ;
C_2H_5MgBr ;

OR

$C_2H_5COCH_3$;
CH_3MgBr ; ***[3 max]***

*If CH_3COCH_3 and CH_3MgBr or $C_2H_5COCH_3$ and C_2H_5MgBr combination given, then award only **[1]**.*