M09/4/CHEMI/HP3/ENG/TZ1/XX/M+

International Baccalaureate®
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MARKSCHEME

May 2009

CHEMISTRY

Higher Level

Paper 3

21 pages

Subject Details: Chemistry HL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the options **[2 x 25 marks]**. Maximum total = **[50 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) determination of structure (of a substance/compound);
determination of the purity (of a substance/compound);
analysis of the composition (of a substance/compound);
separation of mixtures; ***[2 max]***

(b) (O–S–O) bond angle changes;
(S–O) bond (length) stretches;
*Allow **[1]** for S–O bond vibrations if neither of the above points are scored.*

polarity of SO_2 molecule changes; ***[3]***

(c) *Description should include:*
monochromator (to create single wavelength);
(rotating) mirrors/beam splitting;
sample and reference (to compare);
photomultiplier detector; ***[4]***
Allow diagram to show this.

(d) A is Spectrum I **and** B is Spectrum III **and** C is Spectrum II;

A Spectrum I:
only spectrum with a (broad) peak in the range 2500–3300 (cm^{-1}) corresponding to the carboxylic acid functional group / –OH in carboxylic acid / H-bonding in carboxylic acid (so must be a carboxylic acid);

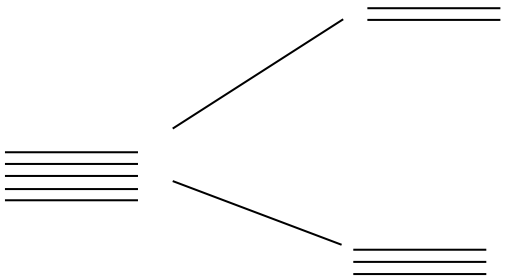
B Spectrum III:
peak in the range 1700–1750 (cm^{-1})corresponding to the carbonyl/C=O group;
but no peak for O–H/no peak at 2500–3300 (cm^{-1}) or 3200–3600 (cm^{-1});

C Spectrum II:
peak in the range 3200–3600 (cm^{-1}) corresponding to the alcohol functional group/OH / the only one without a peak at 1700–1750 (cm^{-1}) corresponding to an alcohol; ***[5]***

A2. (a) D could be $CH_3CH_2COOCH_3$ or $CH_3COOCH_2CH_3$;
this is because there are 3 peaks / 3:2:3 ratio;
explanation of splitting into a singlet a triplet and a quartet;
methyl propanoate/$CH_3CH_2COOCH_3$ is correct isomer because of higher chemical shift value of singlet (3.6 instead of 2.0–2.5); ***[4]***

(b) magnetic resonance imaging (MRI) gives a three-dimensional view of organs in the human body / *OWTTE*;
because protons in water molecules/lipids/carbohydrates in human cells give different signals, depending upon their environment / *OWTTE*; ***[2]***

A3. (a) (i) drawing showing splitting of levels into a low-energy triply degenerate set; high-energy doubly degenerate set; ***[2]***



*Allow **[1]** if drawn with three high lines and two low.*

(ii) the oxidation state affects the size of the d orbital splitting (due to the different number of electrons present); ***[1]***

(iii) colour will be yellow/green/red/pink/orange;
NH_3 ligand causes more splitting of d orbitals than H_2O; ***[2]***

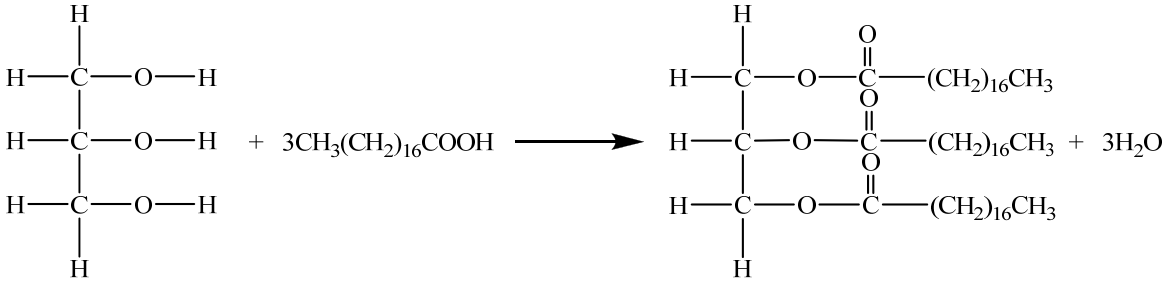
Option B — Human biochemistry

B1. (a) peptide/amide; ***[1]***

(b) hydrogen bonds; ***[1]***

(c) hydrogen bonds;
disulfide bridges/bonds;
ionic interactions/bonds;
van der Waals' forces / hydrophobic interactions / London/dispersion forces / temporary induced dipoles; ***[2 max]***

B2. (a)



correct structure of glycerol **and** correct formula of stearic acid;
correct structure of triglyceride;
$3H_2O$ **and** coefficient of 3 on stearic acid; ***[3]***
Accept displayed or condensed formulas for molecules.

(b) (i) number of grams/amount/mass of iodine/I_2 that add to/react with 100 g of lipid/fat/oil; ***[1]***

(ii) (amount of linoleic acid in 100 g =) $\frac{100}{280.4} = 0.357$ mol;
2 double bonds in molecule so 1 mole of lipid reacts with 2 moles of I_2;
Can be implied in working.

mass of iodine that reacts $(= 253.8 \times 0.357 \times 2) = 181$ g ; ***[3]***
*Award **[3]** for correct final answer.*
*Award **[2]** for 90.5 g.*

(c) LDL is (a) larger (molecule) than HDL;
LDL transports cholesterol to arteries **and** HDL removes cholesterol from arteries;
LDL produced from saturated fats/trans fatty acids;
LDL increases the risk of heart disease/problems; ***[2 max]***
Accept converse statements for HDL.
Do not accept LDL is bad cholesterol and HDL is good cholesterol.

B3. (a) alkene/ketone; ***[1]***
Accept carbonyl.
Do not accept aldehyde.

(b) change release of hormones/FHS/LH (from hypothalamus/pituitary gland);
prevent ovulation / egg release;
prevent attachment of egg to uterus / thin lining of the uterus/endometrium;
prevent sperm from reaching egg / thicken cervical mucus; ***[2 max]***
Do not accept "mimic pregnancy".

B4. (a) *characteristics* ***[2 max]***
enzymes are proteins;
enzyme activity depends on tertiary and quaternary structure/the nature of the active site;
lock and key/induced fit hypothesis;

comparison ***[2 max]***
enzymes function within a narrow pH range;
enzymes are denatured by high temps/temp above 40 °C **and** inorganic catalysts can be used at high temps/are less affected by conditions;
enzymes are very specific **and** inorganic catalysts often catalyse several reactions/non specific; ***[4 max]***

(b) initial rates reduced;
lead binds to enzyme away from active site and changes shape of active site so substrate no longer fits / *OWTTE*;
ritonavir is a similar shape to the substrate and so fits inside active site instead of substrate / *OWTTE*;
lead: K_m unchanged and V_{max} lower;
ritonavir: K_m higher and V_{max} the same; ***[5]***
Accept competitive inhibitor for ritonavir and non-competitive inhibitor for lead.

Option C — Chemistry in industry and technology

C1. (a) main cylinder is made only from carbon hexagons, with pentagons required to close the structure at the ends;
single or multiple walled tubes made from concentric nanotubes can be formed;
bundles of the tubes have high tensile strength;
other substances (elements, metal oxides etc.) can be inserted inside the tubes;
strong covalent bonding / no weak bonds;
behaviour of electrons depends on the length of a tube and hence some forms are conductors and some are semiconductors; ***[4 max]***

(b) hazards associated with small airborne particles are not known / long term effects unknown / *OWTTE*;
may not be covered by current toxicology regulations (as properties depend on the size of the particle) / may be toxic / *OWTTE*;
human immune system may be defenceless against new nanoscale products / *OWTTE*;
(there may be social problems) as poorer societies may suffer as established technologies become redundant and demands for commodities change / *OWTTE*; ***[4]***

C2. (a) *(+) Cathode:*
$2H_2O + O_2 + 4e \rightarrow 4OH^-$;

(–) Anode:
$2H_2 + 4OH^- \rightarrow 4H_2O + 4e$; ***[2]***
If both equations given but at wrong electrodes award ***[1]****.*

(b) *(+) Cathode:*
nickel hydroxide/$Ni(OH)_2$;

(–) Anode:
cadmium hydroxide/$Cd(OH)_2$;

Cell equation:
$Cd + 2H_2O + 2NiO(OH) \rightarrow Cd(OH)_2 + 2Ni(OH)_2$; ***[3]***

(c) neither cause pollution when running;
lead/sulfuric acid are pollutants (making or disposing of battery);
production of hydrogen and oxygen for fuel cells causes pollution; ***[2 max]***

(d) no, since the fuel must be fluid/liquid or gas / the fuel must be continuously supplied to the fuel cell/it must be <u>able to flow</u>; ***[1]***

C3. (a) *thermotropic liquid crystals* are pure substances that show liquid crystal behaviour over a temperature range (between the solid and liquid states);
lyotropic liquid crystals are solutions that show the liquid crystal state at certain concentrations; ***[2]***

(b) strong intermolecular hydrogen bonds between the chains;
intermolecular bonds can be broken (by concentrated sulfuric acid) as O and N atoms are protonated (breaking the hydrogen bonds) / hydrolysis of amide linkage; ***[2]***

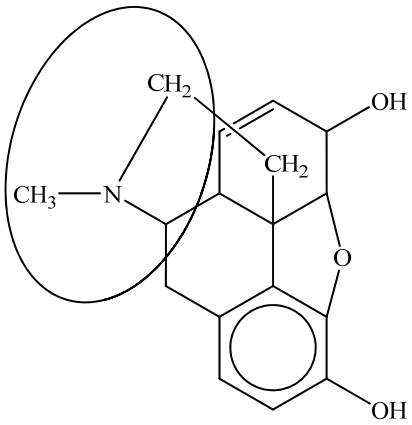
(c) Si has a lower ionization energy (than P or S);
so electrons can flow through the material more easily;
(p-type) has small amount of/is doped with a group 3 element/B/In/Ga;
which produces electron holes/positive holes;
sun/photons cause release of electrons;
electrons move from n-type to p-type material; ***[5 max]***

Option D — Medicines and drugs

D1. (a) aspirin useful in preventing the recurrence of heart attacks/strokes / prevents blood clots;
aspirin reduces fever more effectively/antipyretic;
anti-inflammatory;
paracetamol overdose causes long term damage / easier to overdose on paracetamol / possible liver damage; ***[2 max]***

(b) mild analgesics function by intercepting the pain stimulus at the source / interfere with the production of substances that cause pain/prostaglandins;
strong analgesics work by bonding to receptor sites in the brain / prevent the transmission of pain impulses without depressing the central nervous system; ***[2]***

(c) (i)



any circle around the nitrogen atom / the nitrogen atom and its <u>three</u> neighboring atoms; ***[1]***

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

(iii) ester; ***[1]***

(iv) polar <u>hydroxyl</u> groups in morphine are replaced by less polar/non-polar <u>ester</u> groups;
so facilitate transport into the non-polar environment of the central nervous system / increases the solubility in lipids / *OWTTE*; ***[2]***

D2. (a) alters incoming sensory sensations / alters mood or emotions; ***[1]***

(b) (i) the range over which a drug can be safely administered / $T.I = \frac{LD50}{ED50}$ / ratio of the lethal dose for 50 % population and the effective dose for 50 % of population; ***[1]***

(ii) person needs to take ever larger quantities of a drug to gain the original effect; ***[1]***

(c) (i) combinatorial chemistry and parallel synthesis are used to synthesize a large number of different compounds and screen them for biological activity / a "combinatorial library" is produced; ***[1]***

(ii) starting material covalently bonded to very small (polystyrene) beads;
mix and split process used / beads are reacted together then split and reacted with new substances so all combinations are made / *OWTTE*;
products purified by filtering of beads and washing; ***[3]***

(iii) parallel synthesis can produce smaller, more focused libraries than combinatorial chemistry; ***[1]***

D3. (a) at moderate doses sedation/soothing/reduction of anxiety/impaired judgement;
at higher doses induce sleep/unconsciousness / extremely high dose may cause death/organ failure; ***[2]***

(b) (i) orange to green; ***[1]***

(ii) reduced because oxidation number of Cr decreases / Cr gains electrons; ***[1]***
Explanation needed for mark.

D4. hallucinations / distortions in sound and visual perception;
reduction of appetite/weight loss/insomnia;
both contain benzene ring;
both contain amine/nitrogen attached to carbon; ***[4]***

Option E — Environmental chemistry

E1. (a) H_2O;
N_2O/nitrous oxide/dinitrogen monoxide/nitrogen(I) oxide;
chlorofluorocarbons/CFCs/e.g CCl_2F_2;
O_3/ozone;
SF_6; ***[2 max]***
Do not accept NOx/nitrogen oxides.
Accept names or formulas.

(b) *Gas:* H_2O **and** *reason:* greatest abundance;
Gas: CO_2 / H_2O **and** *reason:* greatest abundance;
Gas: CH_4 / N_2O **and** *reason:* more effective at absorbing radiation;
Gas: CFC / SF_6 more effective at absorbing radiation/very long life in atmosphere; ***[2 max]***

(c) thermal expansion of the oceans / changes in sea temperature affecting sea life;
melting of the polar ice-caps/glaciers / rising sea levels;
floods / droughts / changes in precipitation and temperature;
changes in migration patterns of animals / changes in distribution of species / species more likely to become naturalized;
changes in the yield/distribution of crops;
changes in the distribution of pests/insects/pathogens/disease-carrying organisms; ***[2 max]***
Do not accept "climate change".

E2. (a) amount of oxygen needed to decompose organic matter;
in a specified time/five days / at a specified temp/ $20\,^{\circ}C$; ***[2]***
Second mark can only be awarded if reasonable attempt made to define BOD.

(b) (i) oxygen/gases less soluble in hot water; ***[1]***

(ii) fertilizer causes excessive algal growth so oxygen concentration reduced/effects of eutrophication / *OWTTE*; ***[1]***
Stating eutrophication alone is not sufficient.

(c) (i) gained electrons; ***[1]***

(ii) +4 to +2 / decreases by 2; ***[1]***

(iii) 0.00005/ 5×10^{-5} (moles); ***[1]***

E3. (a) $Cr^{3+}(aq) + 3OH^-(aq) \rightleftharpoons Cr(OH)_3(s)$
correct equation;
correct state symbols; ***[2]***
Equilibrium or normal arrows can be used.

(b) $K_{sp} = [Cr^{3+}][OH^-]^3$; ***[1]***

(c) $1.00 \times 10^{-33} = [Cr^{3+}][OH^-]^3$ **and** $[Cr^{3+}] = 3 \times [OH^-]$;
$1.00 \times 10^{-33} = [Cr^{3+}](3[Cr^{3+}])^3 = 27 \times [Cr^{3+}]^4$
$[Cr^{3+}] = 2.47 \times 10^{-9}$ (mol dm^{-3}); ***[2]***
*Award **[2]** for correct final answer.*
*Award **[1]** for 5.62×10^{-9}.*

E4. (a) $\lambda = 242$ nm / wavelength lower/frequency higher for $O_2 \rightarrow 2O\bullet$ /oxygen dissociation;
$\lambda = 330$ nm / wavelength higher/frequency lower for $O_3 \rightarrow O_2 + O\bullet$ /ozone dissociation;
the bonding in O_2 is stronger than in O_3; ***[2 max]***

(b) $CCl_2F_2 \rightarrow CClF_2 + Cl\bullet$;
$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$;
$ClO\bullet + O\bullet \rightarrow O_2 + Cl\bullet$;
Accept other suitable equations including CFC or Cl radicals.
• not necessary for mark but if + or – used instead penalize once only. ***[3]***

(c) *advantages:* no weak C–Cl bond / not ozone depleting / do not release Cl atoms;
disadvantages: flammability / ability to absorb infrared radiation / increased greenhouse effect / contribute to global warming; ***[2]***

Option F — Food chemistry

F1. (a) (ability to) reflect and absorb different wavelengths/frequencies/colours of visible light; ***[1]***

(b) anthocyanins; ***[1]***

(c) (i) carotenoids; ***[1]***
Do not accept β–carotene.

(ii) presence of (multiple) carbon–carbon double bonds;
loss/bleaching of colour / loss of vitamin A activity / off odours; ***[2]***
Do not accept change of colour.

F2. (a) a substance that delays the onset or slows the rate of oxidation; ***[1]***

(b) antioxidants (AH) stop the formation of free radicals/interrupt the propagation of the free-radical chain/free-radical quenchers/ $ROO\bullet + AH \rightarrow ROOH + A\bullet$;
BHA/ BHT/ TBHQ / vitamin E / beta-carotene / selenium;
chelating agents decrease the concentration of/bind to/remove free metal ions in solution;
salts of EDTA / plant extracts (rosemary, tea, ground mustard);
reducing agents remove or reduce concentrations of oxygen;
ascorbic acid (vitamin C) /carotenoids; ***[6]***

(c) hydroxyl/phenol/alcohol;
alkene/arene/benzene/phenyl; ***[2]***
Accept names or formulas.
Do not accept alkyl groups as functional groups.

(d) *Step 1:*
initiation / formation of free radicals;
$RH \rightarrow R\bullet + H\bullet$;

Step 2:
propagation / free-radical chain reaction;
$R\bullet + O_2 \rightarrow ROO\bullet$ / $ROO\bullet + RH \rightarrow R\bullet + ROOH$;

Step 3:
termination / free radicals combine to form non-radical products;
$R\bullet + R\bullet \rightarrow RR$ / $R\bullet + ROO\bullet \rightarrow ROOR$ / $ROO\bullet + ROO\bullet \rightarrow ROOR + O_2$; ***[6]***

F3. a genetically modified food is derived/produced from a genetically modified organism;
*Award **[1]** for definition.*

benefits:
crops: enhanced taste/quality/appearance;
reduced maturation time;
increase in nutrients and yield;
improved resistance to disease, pests and herbicides;
enrichment of rice with vitamin A;

animals: increased resistance;
productivity and feed efficiency;
better yields of milk/egg;
improved animal health;

environment: "friendly" bio-herbicides and bio-insecticides;
conservation of soil/water/energy;
improved natural waste management;

concerns:
(links to) increased allergies (for people involved in their processing);
altered composition of (balanced) diet / altered nutritional quality of food;
change in ecosystems / development of "superweeds"/"superbugs"; ***[5 max]***
*Award **[4 max]** for benefits and concerns.*
*To score **[4]** both benefits and concerns must appear in answer.*

Option G — Further organic chemistry

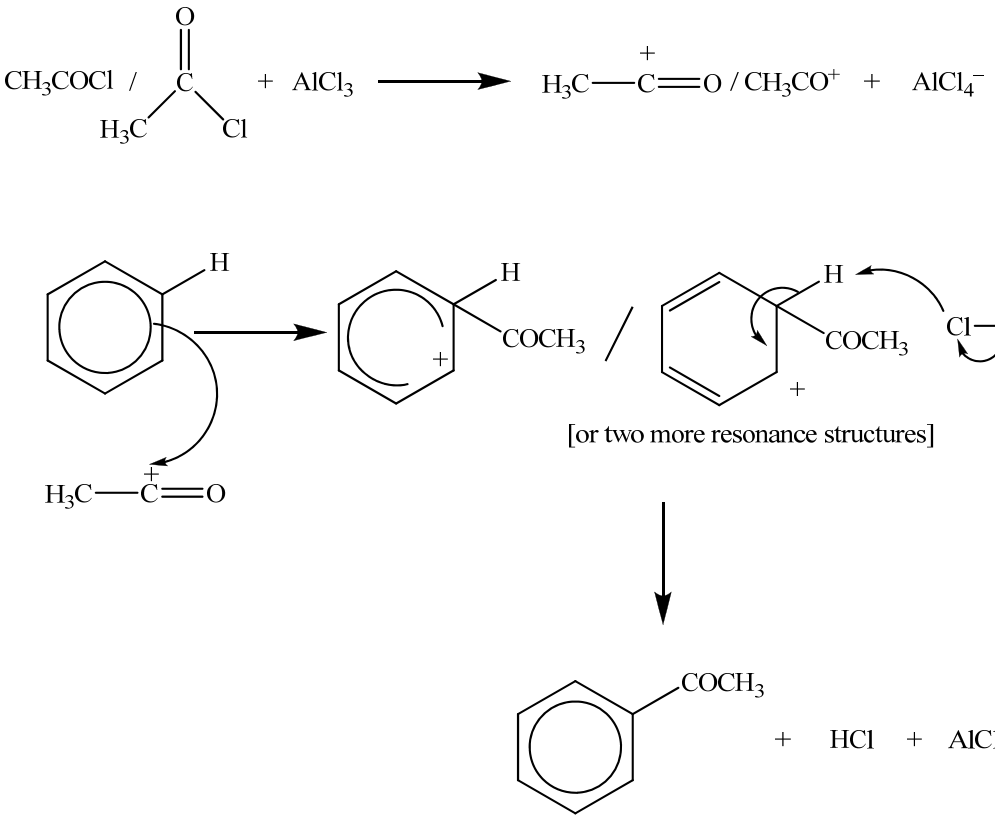
G1. (a) (i) $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$ / $HNO_3 + H_2SO_4 \rightarrow NO_2^+ + H_2O + HSO_4^-$ / $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$

and $H_2NO_3^+ \rightarrow H_2O + NO_2^+$

*Award **[1]** for correct reactions and products and **[1]** for balancing.* ***[2]***

Also accept two step equations or curly arrow equations.

(ii)

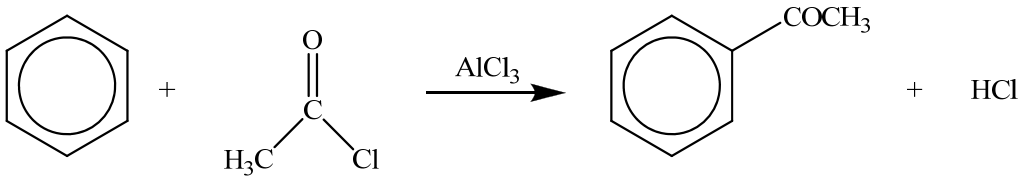


equation showing the formation of the CH_3CO^+ ion;

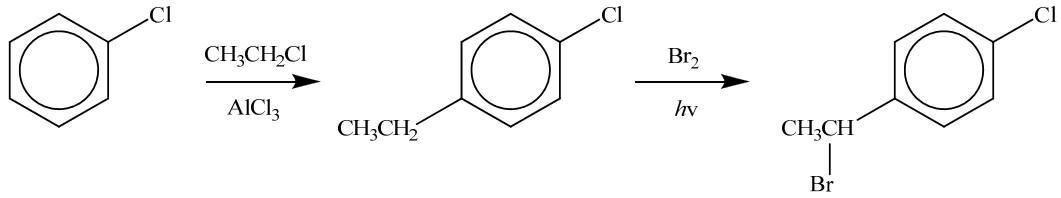
curly arrow going from benzene to electrophile **and** subsequent formation of intermediate correctly represented in mechanism;

curly arrow showing removal of proton and second curly arrow showing the reformation of the aromatic ring to form the new product and hydrogen chloride; ***[3]***

*Award **[1 max]** for the equation:*



(iii)

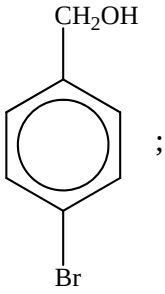


correct reagents and first step;
Chlorobenzene is not necessary for mark.

first product;
reaction with Br_2 **and** UV light in second step; ***[3]***
Accept correct names or condensed formulas in place of structures.
Accept other reasonable suggestions.

(b) (i) reaction with Br_2 **and** UV light (to react with methyl group);
Br_2 and $AlBr_3$ / $AlCl_3$ (to substitute in benzene ring); ***[2]***
Accept in either order.

(ii)

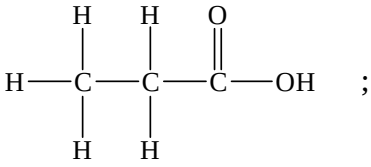


;

(nucleophilic) substitution only on alkyl group/nucleophilic substitution cannot occur on benzene ring / *OWTTE*; ***[2]***

G2. (a) (i) CH_3MgBr/methyl magnesium bromide; ***[1]***

(ii)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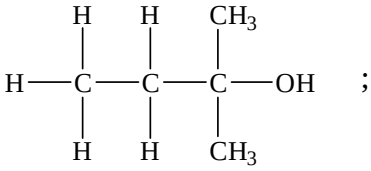
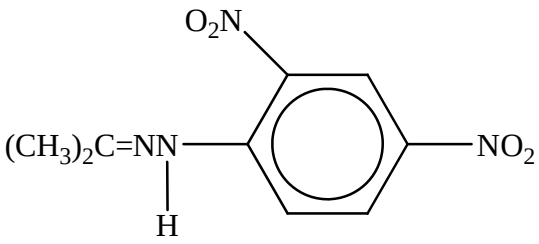

;

[2]

Allow correct condensed structural formula in each case e.g. CH_3CH_2COOH etc.

(b)

A = 
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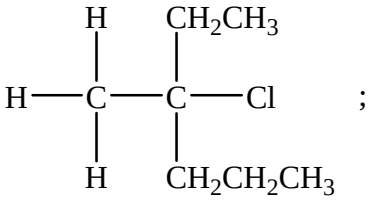
B = 
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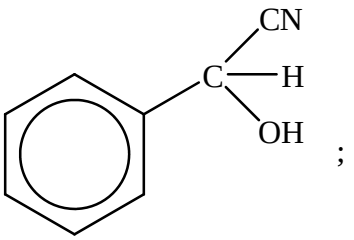
C = 
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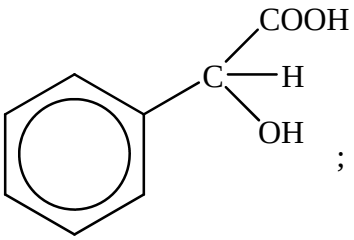
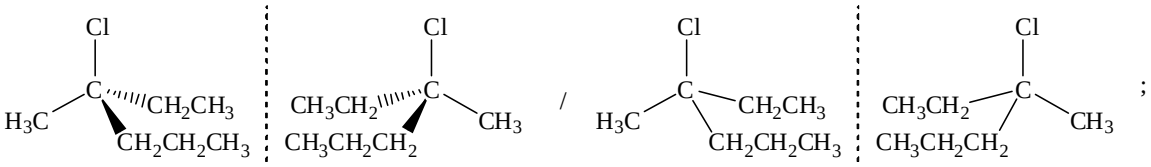
D = 
;

[4]

Allow correct condensed structural formula in each case.
Do not penalize students if they draw a structure that attaches NO_2 to benzene ring via O and not N, also students do not have to show double and triple bonds.

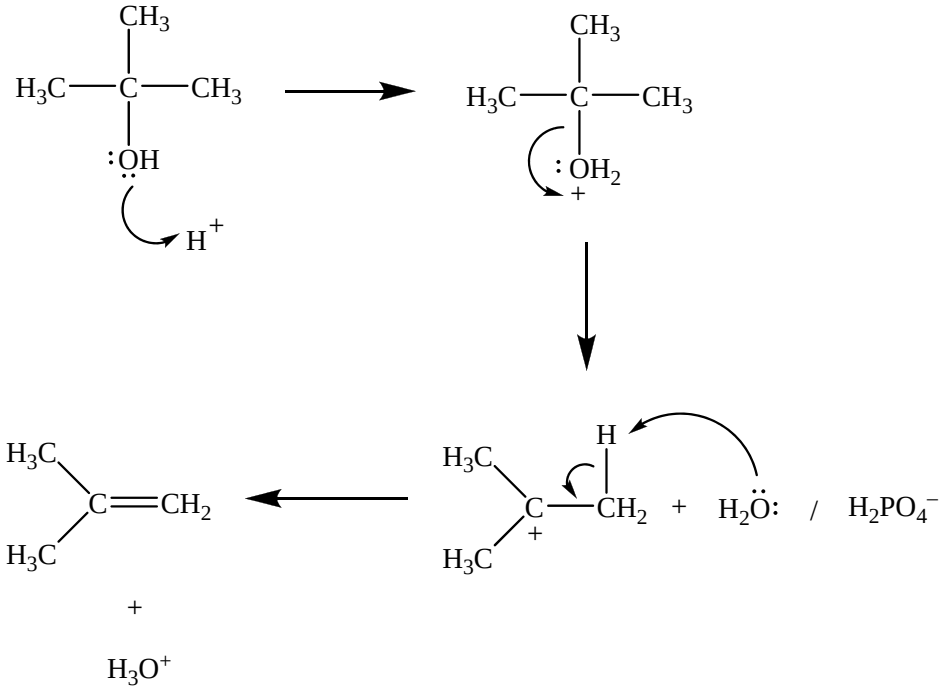
(c)



ECF if wrong structure of B used.
Mirror plane representation not necessary.

B has a chiral/asymmetric carbon/4 different groups attached to the central carbon; ***[2]***

G3.



correct identification of product as $(CH_3)_2C=CH_2$ /methylpropene;

mechanism showing:
curly arrow going from (lone pair of electrons on) O to H^+;
structure of carbocation;
curly arrow from (lone pair on) oxygen of water to H shown; ***[4]***
*Award **[3]** for a concerted mechanism.*
Correct geometry is not required for structure of carbocation.