M13/4/CHEMI/HP3/ENG/TZ1/XX/M

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MARKSCHEME

May 2013

CHEMISTRY

Higher Level

Paper 3

25 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.

2. Each marking point has a separate line and the end is shown 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 ***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. When marking, indicate this by adding **ECF** (error carried forward) on the script.

10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

11. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the markscheme. Similarly if the formula is specifically asked for, unless directed otherwise in the markscheme, do not award a mark for a correct name.

12. 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.

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

Option A — Modern analytical chemistry

Penalize incorrect bonds (eg, C bonded to HO) or missing hydrogens once only in all of Option A.

A1. (a) CH_3COCH_3 **and** CH_3CH_2CHO; ***[1]***
Accept full or condensed structural formulas.
Ignore incorrect names as long as structures are correct.

(b) same/similar (types of) bonds / both contain the carbonyl group/C=O; ***[1]***
Do not accept same functional group.

(c) (mass spectrum of) CH_3CH_2CHO contains peak at $m/z = 29$ / CH_3COCH_3 does **not** contain peak at $m/z = 29$;
(corresponding to) loss of C_2H_5 / $M_r - C_2H_5$ / CHO^+ / loss of CHO / M_r – CHO / $C_2H_5^+$;

OR

(mass spectrum of) CH_3CH_2CHO contains a (strong) peak at $m/z = 57$ / CH_3COCH_3 does **not** contain a (strong) peak at $m/z = 57$;
(corresponding to) loss of H / $M_r - H$ / $CH_3CH_2CO^+$; ***[2]***
Penalize missing + once only in A1.

(d) *m/z = 71:* $CH_3CH_2CH_2CO^+$ / $C_3H_7CO^+$ / $C_4H_7O^+$;
Accept $CH_3COCH_2CH_2^+$.
m/z = 43: $CH_3CH_2CH_2^+$ / CH_3CO^+ / $C_3H_7^+$ / $C_2H_3O^+$; ***[2]***
Penalize missing + once only in A1.

A2. (a) components are adsorbed on stationary phase/silica (gel)/silicon dioxide/SiO_2;
components dissolve in mobile phase/solvent;
Accept soluble instead of dissolve.
Reference must be made to idea of dissolving or solubility for M2.

each component has different affinity for two phases / *OWTTE*;
each component takes a different amount of time to emerge / components move through column at different rates / *OWTTE*; ***[3 max]***

(b) stationary phase is high boiling point liquid/non-volatile liquid/long-chain alkane/high boiling point alkane/hydrocarbon/grease/wax adsorbed/coated on solid/silica/silicon dioxide/SiO_2/alumina/aluminium(III) oxide/Al_2O_3 (support);
Allow high boiling point oil.
Allow oxide instead of silica or alumina.

mobile phase is inert gas/nitrogen/helium/argon;
Do not accept just gas.

liquids vaporized in oven/at high temperature;
liquids/components have different retention times/move through tube at different speeds; ***[4]***
Accept area under peak is proportional to quantity/amount as another marking point.

(c) cannot be used as sugars decompose/are not stable at high temperatures / cannot be used as sugars react at the high temperature used in GLC; ***[1]***

A3. (a) (ratio of) area under each peak / integration trace; ***[1]***
Accept size of peak but not height of peak.

(b) $CH_3CH_2COCH_2CH_3$; ***[1]***

(c) quartet / 1:3:3:1; ***[1]***

A4. (a) (i) radio waves; ***[1]***

(ii) microwaves / IR/infrared; ***[1]***

(b) *Similarity:*
lines / only certain frequencies/wavelengths/energies / discrete / not continuous / absorptions and emissions occur at the same frequencies/wavelengths;

Difference:
emission spectra have only a few frequencies/bright lines while absorption spectra show all frequencies/have a coloured background except for a few missing/black lines / *OWTTE*; ***[2]***
Accept emission spectra have fewer frequencies included than absorption spectra.
Accept a suitable diagram to illustrate one or both points.

A5. (a) *Any two for **[1]**, any three for **[2]**.*
metal ion
oxidation number/state / charge on ion
ligand
stereochemistry / geometry / shape of complex ion ***[2]***
Do not allow arrangement of ligands as an alternative to stereochemistry.
Allow transition metal/element / nature/identity of (transition) metal/element as an additional marking point to those listed above.

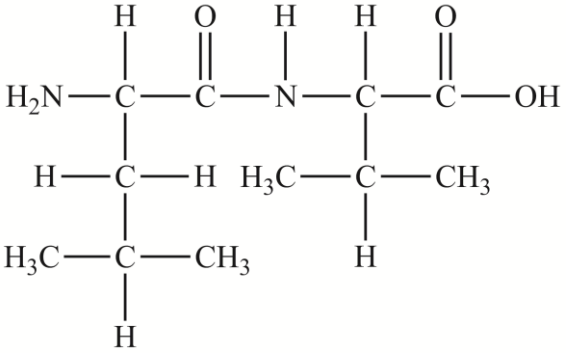
(b) absorbance proportional to concentration / direct relationship between absorbance and concentration; ***[1]***

(c) 0.64 (ppm); ***[1]***
Accept answers in the range 0.63–0.65 ppm.

Option B — Human biochemistry

Penalize incorrect bonds (eg, C bonded to HO) or missing hydrogens once only in all of Option B.

B1. (a) (i)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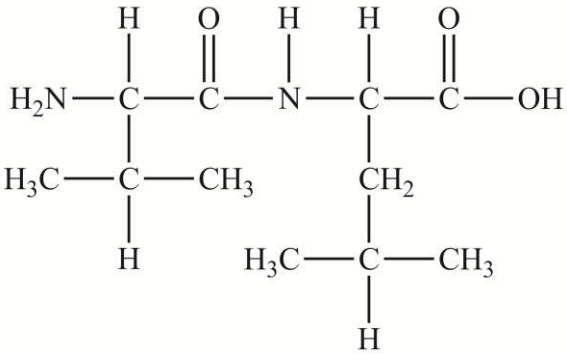

;

[2]

Accept full or condensed structural formulas.
Penalize incorrect representation of peptide link (COHN or NHOC) once.
*Award **[1]** for a correct peptide link if the rest of the structure is incorrect.*

(ii) water/H_2O; ***[1]***

(b) sample of amino acids/mixture placed/spotted on gel/polyacrylamide/PAGE/ paper **and** buffer solution/solution of known pH;
potential difference/voltage applied;
Do not accept current.
Allow potential for potential difference.
Allow electric field applied.

if the (amino acid's) isoelectric point is below the pH (of buffer) it is negatively charged / if the (amino acid's) isoelectric point is above the pH (of buffer) it is positively charged;
different amino acids move different distances/rates according to their charge/isoelectric point / different amino acids move at different rates towards oppositely charged electrodes / *OWTTE*;
spray/develop with ninhydrin/organic dye / detected by staining/fluorescence under UV light;
measure distance travelled **and** compare with standards/isoelectric points; ***[4 max]***

(c) *Any two for **[1]***
structural / growth / repair
Allow more specific function eg, forms tendons/muscles/eye lens/nails/hair, repair of tissue/cells etc.

enzyme / biological catalyst
hormone / chemical messenger
transport of molecules
Allow movement/carriage of molecules, and chemicals instead of molecules / OWTTE.
Do not award mark for transport alone.

storage of molecules
Do not award mark for storage alone.
Allow chemicals instead of molecules / OWTTE.

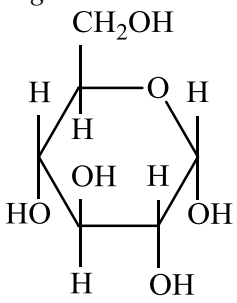
lubrication
(to make/produce) immunoproteins/antibodies
energy source **[1]**
Do not accept energy storage.
Allow more specific examples of any of the above.

B2. (a) contain carbonyl (group)/C=O;
have at least two hydroxyl/OH (groups);
Do not accept hydroxide instead of hydroxyl.

CH_2O empirical formula; **[2 max]**
Do not accept $C_xH_{2y}O_y$ or $C_6H_{12}O_6$.

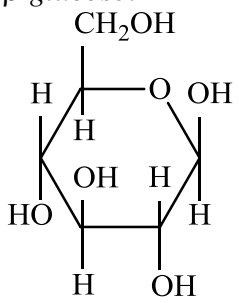
(b) (i)

α-*glucose*:



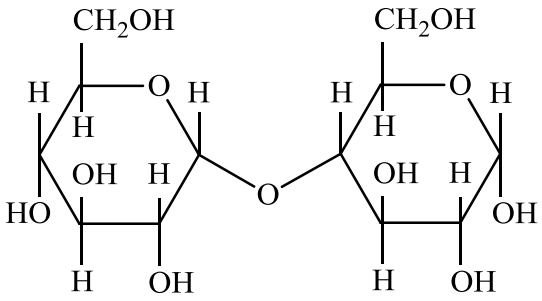
;

β-*glucose*:



; **[2]**

*Award **[1 max]** if position of OH is correct in both structures at C1 but other groups/moieties (eg, CH_2OH) or H are missing.*
*Award **[1 max]** if the alpha and beta structures are labelled in reverse.*

(ii) 

;

[1]

B3. (a) both fat soluble;
both contain mainly non-polar/hydrocarbon parts (and only one OH group) / *OWTTE*; ***[2]***
Do not award ECF if water soluble is stated for either vitamin.
Do not award M2 for answers such as "since both do not have many OH groups present".

(b) rickets / bone deformation; ***[1]***

B4. (a) (i) proteins;
enzyme activity depends on tertiary and quaternary structure/nature of active site;
lock and key / induced fit (hypothesis/theory); ***[2 max]***
Allow enzymes are specific (for a particular reaction).

(ii) enzymes function over small pH range **and** inorganic catalysts function over wider pH range;
enzymes denatured above 40 °C **and** inorganic catalysts used at high temperatures/less affected by conditions;
Allow high temperature instead of above 40 °C.

enzymes are very specific **and** metal-based inorganic catalysts often catalyse several reactions/are non specific;
enzymes are only homogeneous but metal-based inorganic catalysts can be heterogeneous and homogeneous/are usually heterogeneous;
enzymes increase rates of reaction by 10^3 to 10^6 **and** metal-based inorganic catalysts increase rates of reaction by a much smaller amount;
enzymes can be regulated by inhibitors/activators **and** metal-based inorganic catalysts typically will not be regulated by other substances;
both decrease activation energies/E_{act} (by providing an alternative pathway); ***[2 max]***

Allow answers where an implied comparison is clearly written for example enzymes work over a much narrower temperature range etc.
*Award **[1 max]** if two appropriate aspects are given for one type of catalyst alone without comparing both of these to the other.*

(b) (i) initial rates reduced; ***[1]***

(ii) *Competitive inhibitors:*
(similar shape to substrate so) fits inside active site instead of substrate / *OWTTE*;

Non-competitive inhibitors:
binds to enzyme not at active site **and** changes shape of active site so substrate no longer fits / *OWTTE*; ***[2]***
Allow at allosteric site instead of not at active site.

(iii)

	V_{max}	K_m	
Competitive	same	higher	;
Non-competitive	lower	same	;

[2]

*Award **[1 max]** for both V_{max} correct.*
*Award **[1 max]** for both K_m correct.*

Option C — Chemistry in industry and technology

Penalize incorrect bonds (eg, C bonded to HO) or missing hydrogens once only in all of Option C.

C1. (a) adding/dissolved in cryolite/Na_3AlF_6; ***[1]***

(b) mining bauxite/ore destroys landscape;
purification of bauxite/ore produces red mud/iron(III) oxide/pollutants;
fluoride as waste product needs to be removed / *OWTTE*;
Allow fluorine waste products/fluorine as waste product needs to be removed.

extraction requires large amounts of electricity from power stations which can emit pollutants / *OWTTE*;
Accept specific examples for power stations (for example nuclear etc.).

global warming caused by CO_2 produced; ***[2 max]***

C2. (a)

Substance	Use	
chlorine	disinfectant / water purification / bleach / manufacture of chlorinating solvents/ pesticides/HCl/PVC/pharmaceuticals/phosgene	;
sodium hydroxide	manufacture of soap/paper/textiles/drain-cleaner/polymers/ pharmaceuticals / oil-refining / production of aluminium *Accept used in neutralization reactions.*	;
hydrogen	fuel / manufacture of margarine/ammonia/methanol/HCl / oil-refining / reduction of metal ores	;

[3]

*Award **[1 max]** for correct identification of three substances if uses are not given or are incorrect.*

(b) $Na^+(aq) + e^- + Hg(l) \rightarrow Na–Hg(l)/Na/Hg(l)$; ***[1]***
Accept e instead of e^-.
Accept $Na^+(aq) + e^- \rightarrow Na(l)$.

C3. (a) $C_{10}H_{22}$: gasoline/petrol / fuel / kerosene;
Do not allow just combustion or cars.
Allow gas for cars/automobiles instead of gasoline but not gas alone.

C_2H_4: chemical feedstock / *OWTTE*; ***[2]***
Accept suitable example such as manufacturing plastics/polymers but not just plastics.

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

(c) solid surface has active sites / reactants adsorb on solid surface;
Do not accept absorb instead of adsorb.

brings reactants close together in correct orientation;
weakens reactant bonds / reactants bonds are easier to break; ***[2 max]***

(d) can be easily removed/filtered from reaction mixture / large amount of reactant molecules pass over catalyst that is in a fixed position / can be used at high temperatures; ***[1]***

C4. (a) polarity / presence of dipole (moment); ***[1]***

(b) *Any two for **[1]***
graphite
cellulose
(spider) silk
DNA
biphenyl nitriles
soap
Kevlar ***[1]***

(c) *Thermotropic liquid crystals:*
pure substances **and** exhibit liquid-crystal properties in a certain temperature range;

Lyotropic liquid crystals:
solutions **and** exhibit liquid-crystal properties in a certain concentration range; ***[2]***

*Award **[1 max]** for thermotropic pure substances **and** lyotropic solutions.*
*Award **[1 max]** for thermotropic in a certain temperature range **and** lyotropic solutions in a certain concentration range.*

C5. (a) (i) *Isotactic:* methyl groups all oriented on same side of polymer chain **and**
Atactic: methyl groups oriented randomly; ***[1]***
Diagram alone is not sufficient – unless difference stated in words.

(ii) closer packing of isotactic chains;
isotactic has stronger van der Waals'/London/dispersion/intermolecular forces (than atactic); ***[2]***
Accept opposite statements for atactic.
Allow vdW as abbreviation for van der Waals' or FDL for London/dispersion.

(b) (i) $HOOC–C_6H_4–COOH$;
$HOCH_2CH_2OH$; ***[2]***
Accept condensed or full structural formulas.

(ii) polyethylene terephthalate (PET);
(permanent) dipole-(permanent) dipole interactions in PET;
both polymers contain van der Waals'/London/dispersion forces between chains / polypropene only has van der Waals'/London/dispersion forces which are weaker than dipole-dipole interactions; ***[3]***
Allow vdW as abbreviation for van der Waals' or FDL for London/dispersion.
M2 and M3 can only be scored if M1 is correct.

Option D — Medicines and drugs

Penalize incorrect bonds (eg, Pt bonded to H of H_3N) or missing hydrogens once only in all of Option D.

D1. (a) *Moderate dosage:*
relieves anxiety
Allow calmness/soothing effect/causes one to relax.

relaxes muscles
induces sedation / slows down mental activity
lowers heart rate
Allow induces sleep but not for both moderate and high.
Allow fatigue for induces sleep.

increases respiration/breathing rate
dilation of pupils of the eyes
constriction of arteries
sweating

High dosage:
induces sleep / loss of consciousness
Allow fatigue for induces sleep.
Accept coma/death.
Allow hypnosis.

alters perception
slurred speech
loss of balance / staggering ***[1]***

*Any one effect for moderate dosage **and** any one effect for high dosage needed for mark.*

(b) (i) $K_2Cr_2O_7$; ***[1]***

(ii) orange to green; ***[1]***
Allow yellow instead of orange.

(iii) +3/III; ***[1]***
Do not allow incorrect notation such as 3+ or 3.

(iv) $3CH_3CH_2OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3CH_3CO_2H + 4Cr^{3+} + 11H_2O$
correct formulas of CH_3CH_2OH and $Cr_2O_7^{2-}/K_2Cr_2O_7$ as reactants **and** CH_3CO_2H/CH_3COOH and Cr^{3+} as products;
full balanced chemical equation; ***[2]***
M2 can only be scored if M1 is correct.
Allow full balanced chemical equation to produce ethanal, $3CH_3CH_2OH + Cr_2O_7^{2-} + 8H^+ \rightarrow 3CH_3CHO + 2Cr^{3+} + 7H_2O$.
Accept full or condensed structural formulas.

(v) ethanoic acid; ***[1]***
Allow acetic acid.
Allow ethanal/acetaldehyde.

(c) infrared (spectroscopy)/IR;
CH characteristic band (at 2950 cm^{-1}) for ethanol / C–H bonds in ethanol absorb at certain frequency/wavelength;
Do not award M2 for CH characteristic band if however wavenumber range/value is given for OH (eg, 3200–3600 cm^{-1} or value in between or even 2500–3300 cm^{-1}).

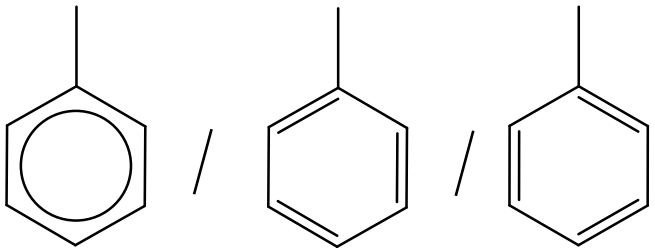
area under peak used to measure concentration (of ethanol);
Accept "size of" instead of "area under".
Do not accept "height" instead of "area under".

OR

fuel cell;
ethanol converts/oxidized to CO_2 and H_2O;
(energy released converted to) voltage/potential difference (which is) proportional to/can be used to measure concentration (of ethanol); ***[3]***
Allow potential instead of potential difference.

D2. (a) *Any two for **[1]***
increase brain activity/concentration/mental alertness
Allow just increase alertness/wakefulness.

increase heart rate
increase rate of breathing / increases respiratory rate / relaxes air passages / helps breathing
palpitations/tremors/shakes
reduces appetite
insomnia/sleeplessness/fits/restless behaviour/agitation/hallucinations/delusory behaviour ***[1]***

(b) (i)  ; ***[1]***
Accept either delocalized or Kekulé structure.
Do not allow just C_6H_5–.
Do not allow benzene ring on its own without the bond extending toward a substituent (which may be also given as R).

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

D3. (a) (i) square planar/coplanar; ***[1]***

(ii)

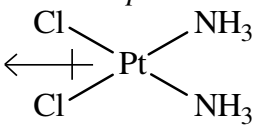
Cisplatin Transplatin

[1]

Tapered wedge-dash bonds not necesssary.

(iii) *Cisplatin:* 90° **and** *Transplatin:* 180°; ***[1]***
Do not apply ECF for bond angle if tetrahedral given in (a) (i).

(iv) cisplatin polar **and** diagram of cisplatin showing net dipole moment; ***[1]***
For example:



Allow any diagram showing idea of a net dipole moment.
ECF may be applied here however as per general marking instructions if tetrahedral given in (a) (i).

(v) binding of cisplatin to DNA/guanine requires both chlorines to be on same side of complex / *OWTTE*; ***[1]***

(b) two (polar) hydroxyl groups/OHs in morphine replaced by ester groups in diamorphine;
Do not allow hydroxide for hydroxyl.
Accept two alcohols instead of hydroxyl.

diamorphine less polar / morphine more polar;
diamorphine capable of rapid penetration of (lipid-based) blood-brain barrier / diamorphine more quickly absorbed into non-polar environment of central nervous system/CNS / *OWTTE*; ***[3]***
Allow diamorphine more soluble/easily dissolved in lipids/fatty tissue.

(c) *Aspirin:*
carboxyl/carboxy/COOH made more polar by converting it to carboxylate/ COO^-/anion (and administering it as sodium salt) / salt of carboxyl/carboxy group more polar than carboxyl/carboxy/COOH / *OWTTE*;
Allow carboxylic acid for carboxyl/carboxy.
carboxylate/COO^- / anion returns to unionized/undissociated form in stomach (since acidic) which then allows easier distribution around the body / *OWTTE*;

Fluoxetine hydrochloride:
salt of amine/ammonium group more polar than amine (in fluoxetine);
Allow amino for amine group.
(more) polar substances more soluble in water/concentrated in bloodstream (and hence can be distributed more easily around the body) / less polar/non-polar substances more soluble in fatty tissues/easier to pass through blood-brain barrier / *OWTTE*; ***[4]***

Option E — Environmental chemistry

E1. (a) specific CFC compound; ***[1]***
Accept CFC/chlorofluorocarbon.
Allow water vapour.

(b)

Environmental Concern	Impact	Way to reduce impact
Global warming	melting of polar ice/thermal expansion causes flooding of some coastal areas/rising sea levels / *OWTTE*; *Do not allow flooding of coastal areas/rising sea levels alone.* climate change affects crop yields/ biodistribution/spread of certain microorganisms / *OWTTE*; *Do not accept climate change on its own. Accept specific examples.* more extremes of weather conditions / desertification; ***[1 max]*** *Accept specific examples of extreme weather (eg, stronger hurricanes).* *Do not allow generic answers such as changes in precipitation, changes in temperature, increase in Earth's temperature.*	decrease consumption of fossil fuels */ OWTTE*; *Accept practical suggestion for reducing fuel consumption (for example, car pooling) or use of alternative energy sources.* *Do not allow answers such as "using the car less decreases CO_2".*
Ozone depletion	more UV radiation causes skin cancer/ cataracts/decrease of plankton/damage to plants / *OWTTE*; *Do not allow general terminology such as skin damage, skin problems, eye problems etc.*	use alternatives to CFCs; *Accept specific alternatives to CFC (for example, alkanes).* *Do not allow "decrease CFCs / use less CFCs".*

[4]

(c) ozone depletion requires higher wavelength / oxygen dissociation requires lower wavelength;
M1 must refer to wavelength.
wavelength inversely proportional to energy / wavelength increases as energy decreases;
oxygen has double bond/bond order of 2 **and** ozone has bond order of 1.5/intermediate bond between single and double;
Stating that ozone has resonance or delocalization alone is not sufficient.
ozone weaker bond / O–O bond energy in ozone lower; ***[3 max]***
Accept opposite argument of oxygen for M4.

E2. (a) waste in landfills takes a long time to decompose while incineration is fast/immediate;
Accept waste in landfills takes a longer time to decompose.

waste in landfills takes up (much) more space than incinerated waste;
landfills produces less toxic gases than incineration / incineration produces HCl/dioxins while landfills do not;
landfills produce methane which is used as a fuel **and** heat energy from incineration can also be used;
landfills cause toxins to leach/enter into soil/ground water/water table while incineration does not / *OWTTE*; ***[4 max]***
Do not allow a mark for stating landfills are cheap whereas incineration is an expensive process.
Accept opposite statements for incineration.
*Award **[3]** if four distinct points are given without a comparison, **[2]** for three, **[1]** for two.*

(b) *Any two for **[1]***
metal
glass
paper
plastic
biomass ***[1]***

E3. (a) leaches/removes nutrients from soil;
Accept specific ions for nutrients.

plant leaves are damaged;
Do not allow just damages plants.

increasing aluminium concentration in the soil;
root damage;
limestone buildings/rocks/statues react with acid;
lakes become acidic killing fish;
toxic metal ions leached/enter into water supplies; ***[3 max]***

(b) redox / oxidation-reduction;
Do not accept reduction or oxidation on their own.

$2NO + 2CO \rightarrow N_2 + 2CO_2$; ***[2]***
Accept equation between NO and a hydrocarbon in petrol.

(c) $H_2O + O_3 \rightarrow 2HO\bullet + O_2$ / $H_2O + O\bullet \rightarrow 2HO\bullet$;

$HO\bullet + NO \rightarrow HNO_2$;
$2HNO_2 + O_2 \rightarrow 2HNO_3$;

OR

$2NO + O_2 \rightleftharpoons 2NO_2$;
Do not penalize missing equilibrium sign.

$HO\bullet + NO_2 \rightarrow HNO_3$; ***[3]***

Accept representation of radicals without • if consistent throughout.

E4. (a) (K_{sp} =) $[Pb^{2+}][SO_4^{2-}]$; ***[1]***

(b) $[Pb^{2+}][SO_4^{2-}] / 2.32\times10^{-6}\times4.15\times10^{-3}/9.63\times10^{-9}$ is less than $K_{sp} / 1.80\times10^{-8}$; ***[1]***

(c) $(1.80\times10^{-8} = 2.32\times10^{-6}\times[SO_4^{2-}])$, $[SO_4^{2-}] = 7.76\times10^{-3}$ (mol dm^{-3});
increase in $[SO_4^{2-}]$ $(= 7.76\times10^{-3} - 4.15\times10^{-3}) = 3.61\times10^{-3}$ (mol dm^{-3}); ***[2]***
*Award **[2]** for correct final answer.*

Option F — Food Chemistry

F1. (a) substance that delays onset/slows rate of oxidation; ***[1]***
Some indication of slowing required. Do not allow prevention of oxidation.

(b) (i) selenium/Se; ***[1]***

(ii) shellfish/tuna/fish / red meat/beef / eggs / grains/cereals/corn/wheat/rice / nuts / chicken / turkey / garlic / nuts / legumes/soybeans / cheese; ***[1]***
Accept other correct food source of Se.
Do not apply ECF from (b) (i) ie, food must be based on Se.

(c) (i) 2-BHA
3-BHA
BHT
THBP ***[2]***
*Award **[2]** for all (four).*
*Award **[1]** for three.*
Accept all.

(ii) THBP does not contain t-butyl group / no; ***[1]***

(iii) (free) radical scavenger / reacts with (free) radicals which could oxidize food / *OWTTE*; ***[1]***

F2. (a) dye is water-soluble **and** pigment is not soluble in water; ***[1]***
Reference to water must be made at least once.

(b) (i) carotenoids/carotenes; ***[1]***

(ii) colour masked changing light-absorption properties (resulting in colour variation) / protein holds pigment/astaxanthin tightly / protein forms a complex with the pigment/astaxanthin / *OWTTE*; ***[1]***
Do not allow protein combines with pigment.

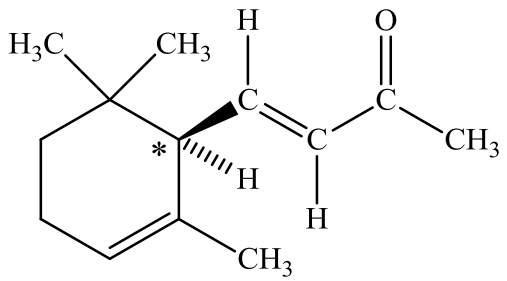
(iii) (astaxanthin stable in heat but high temperature causes) protein to change shape/denature/uncoil/break down / *OWTTE*;
cartenoid pigment released from the protein (allowing red colour to appear) / other colours absorbed / *OWTTE*; ***[2]***
M2 can only be scored if M1 is correct.

F3. (a) (i) RCH=NR′; ***[1]***
Allow RCHNR′.

(ii) water/H_2O; ***[1]***

(b) rearrangement / dehydration / fragmentation / degradation / formation of heterocyclic (nitrogeneous) compounds / polymerization / reduction; ***[1]***
Allow fission.

F4. (a) identification of chiral centre *; ***[1]***



(b) *R,S:*
absolute/spatial configuration of groups around chiral carbon/centre;
Allow arrangement instead of configuration.
Allow R,S based on order/priority of groups around chiral carbon/centre.
*Allow R: (based on) rectus/right/clockwise **and** S/sinister/left/counter-clockwise system around chiral carbon/centre worked out by looking at structure of molecule / OWTTE.*
Do not award mark unless reference is made to chiral carbon/centre.

+(d),–(l):
rotation of <u>plane</u> polarized light clockwise for +(*d*) **and** counter-clockwise for –(*l*); ***[2]***

(c) R;
priority groups (according to atomic number only) ordered clockwise (according to Cahn-Ingold-Prelog/CIP convention); ***[2]***
Do not award mark if reference is made to molecular/molar mass.

(d) binds to receptor site differently; ***[1]***

(e) +(*d*) *limonene:* tastes of oranges **and** –(*l*) *limonene:* tastes of lemons; ***[1]***

F5. (a) $RH \xrightarrow{(hv)} R\bullet + H\bullet$
hv/hf/sunlight not required in equation.

$R\bullet + O_2 \rightarrow ROO\bullet$
$RH + ROO\bullet \rightarrow R\bullet + ROOH$ ***[2]***
Accept representation of radicals without • if consistent throughout.
*Award **[2]** for all three correct, **[1]** for any two correct.*

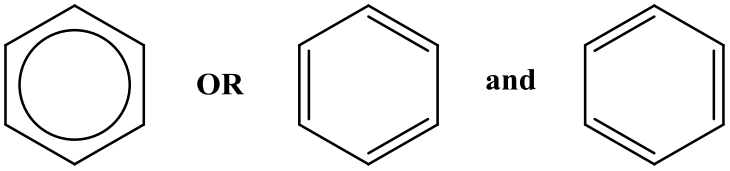
(b) O–O (bond) breaks easily/is weak **and** carbonyl / carboxyl / aldehyde; ***[1]***
Accept ketone for carbonyl, carboxylic/alkanoic acid for carboxyl.
Accept formula (eg, RCOOH etc.).
Allow hydroperoxides degrade because they are unstable instead of O–O (bond) breaks easily/is weak.

Option G — Further organic chemistry

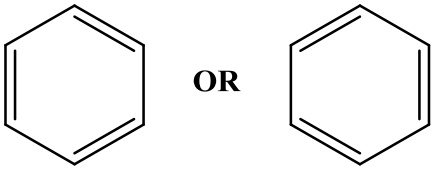
Penalize incorrect bonds (eg, C bonded to HO) or missing hydrogens once only in all of Option G.

G1. (a) six-membered ring (of carbon atoms) / hexagonal;
planar;
Allow flat.

all carbon to carbon bond lengths equal / all bonds have bond order of 1.5 / all carbon to carbon bonds intermediate between single and double;
resonance/delocalization;
all bond angles 120° ; ***[3 max]***
Accept all carbons sp^2.
*Award **[2 max]** for representation of full delocalized benzene structure or two Kekulé structures without any explanations.*
For example:



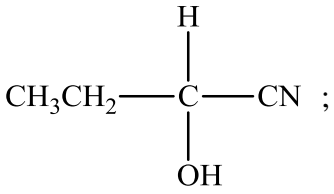
*Award **[1 max]** for one Kekulé structure or for the name cyclohexatriene without any explanations.*
For example:



(b) (bromomethyl)benzene/$C_6H_5CH_2Br$ reacts faster (with hydroxide/nucleophile);
Accept opposite argument for bromobenzene.

(Bromomethyl)benzene/$C_6H_5CH_2Br$:
electron deficient carbon of $–CH_2Br$ group susceptible to attack by nucleophiles / *OWTTE*;
Bromobenzene/C_6H_5Br:
nucleophiles repelled by electron cloud on benzene / C–Br bond stronger / strong pull of electronegative Br decreases electron deficient/δ^+ C (in C–Br bond), so less likely to be open to attack by nucleophiles / benzene ring prevents nucleophile attacking from opposite direction to the C–Br bond / lower polarity of C–Br bond / *OWTTE*; ***[3]***
Allow more detailed explanation for M3 such as interaction between p-electrons/lone pairs/non-bonding electrons on Br with (π-)delocalized electrons of benzene ring which makes C-Br bond stronger / OWTTE.

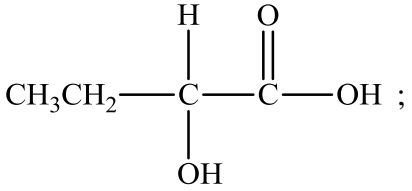
G2. (a) (i) **A:**



;

[1]

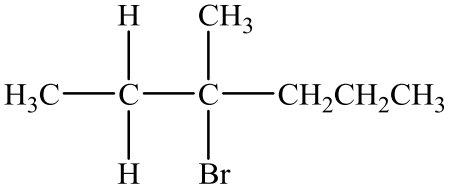
(ii) **B:**



;

[1]

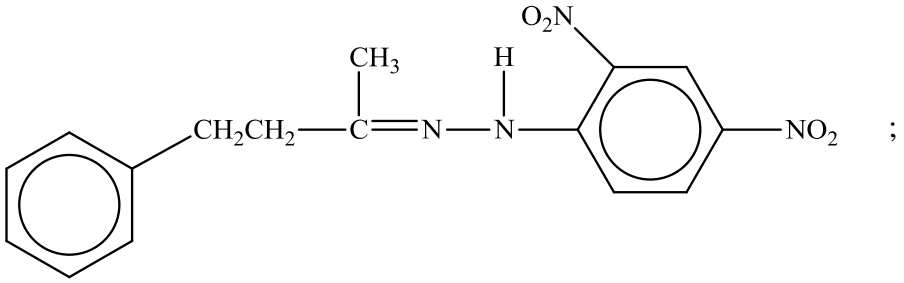
(b) **C:**



;

[1]

(c) **D:**

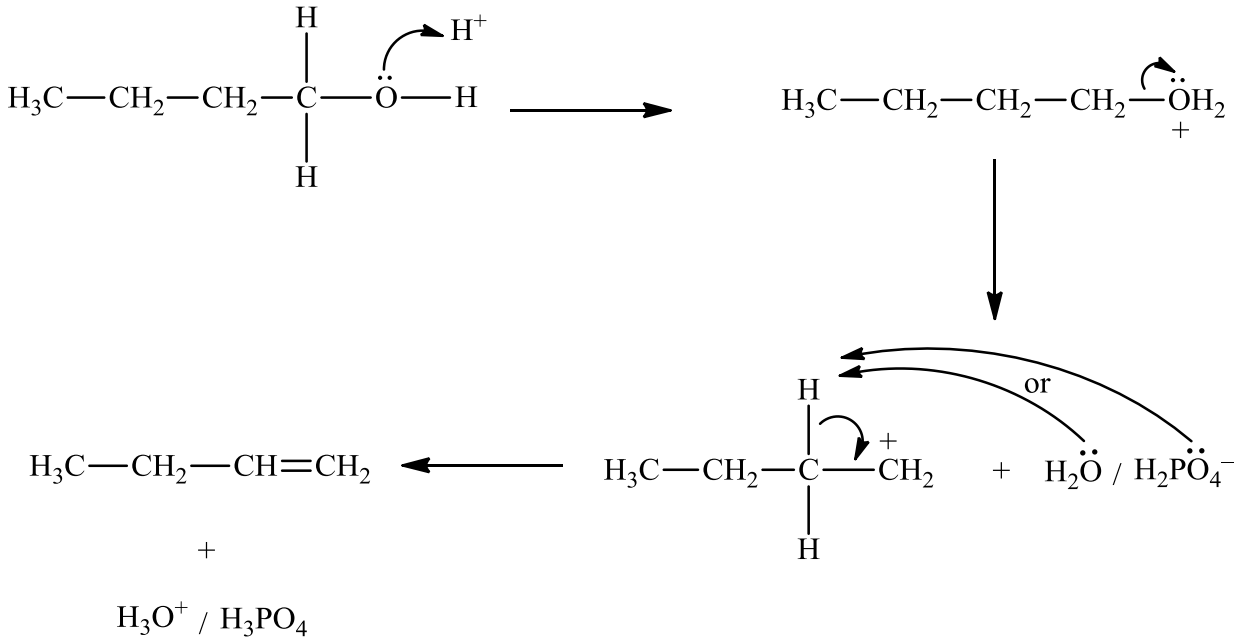


;

[1]

Accept full or condensed structural formulas throughout G2.

G3. (a)

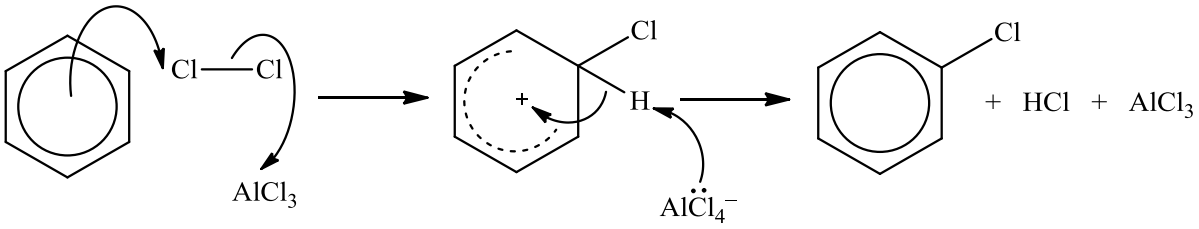


curly arrow going from lone pair on O to H^+;
curly arrow showing H_2O leaving **and** representation of positively charged O intermediate;
curly arrow going from lone pair on O of $H_2O/H_2PO_4^-$ to H **and** curly arrow going from CH bond to $C–C^+$ to form C=C;
No mark for M3 if C^+ is not represented.

formation of organic product $CH_3CH_2CH=CH_2$ **and** H_3O^+/H_3PO_4; ***[4]***

(b) sulfuric acid is an oxidizing agent / side-products can occur using sulfuric acid / *OWTTE*; ***[1]***
Allow charring.
Allow opposite statement for phosphoric acid (eg, not complicated by side-reactions / OWTTE).
Do not accept answers such as "phosphoric acid has more protons".

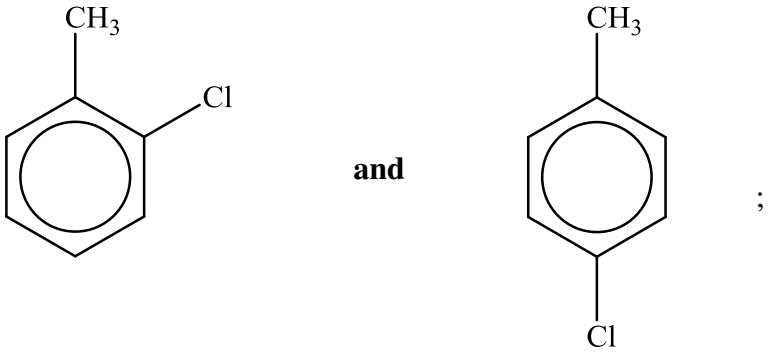
G4. (a)



curly arrow going from delocalized electrons in benzene to Cl in Cl_2 (and curly arrow going from Cl–Cl bond to $AlCl_3$);
Allow curly arrow going from delocalized electrons in benzene to Cl^+ for M1.

representation of carbocation with correct formula **and** positive charge on ring;
curly arrow going from lone pair/negative charge on Cl in $AlCl_4^-$ to H **and** curly arrow going from CH bond to benzene ring;
formation of organic product chlorobenzene **and** HCl **and** $AlCl_3$; ***[4]***
Allow other suitable catalysts such as $FeCl_3$ etc.
Allow mechanism with corresponding Kekulé structures.

(b) (i)



;

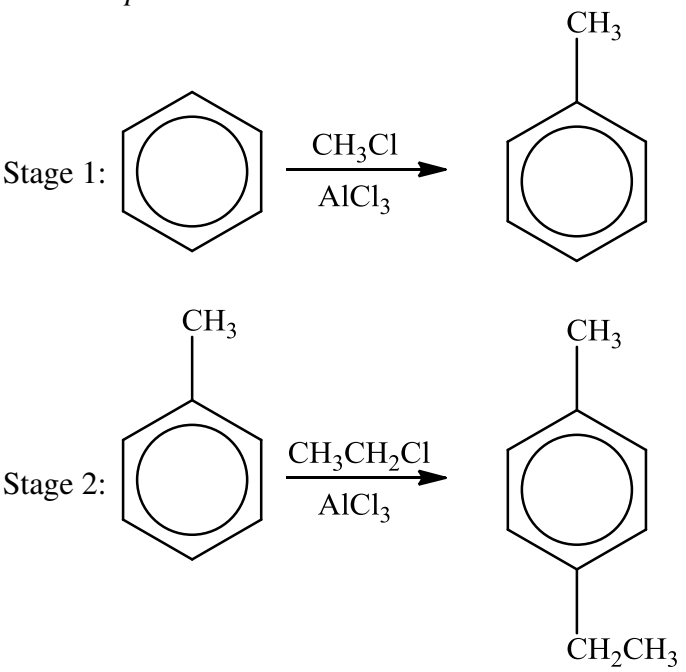
1-chloro-2-methylbenzene *1-chloro-4-methylbenzene* ***[1]***

(ii) positive inductive/electron releasing/donating effect of methyl group stabilizes intermediate carbocation on ring when electrophile adds at 2-/*o* or 4-/*p* position / *OWTTE*;
Allow activating group instead of electron releasing for methyl.
Accept diagram showing stabilization of intermediate carbocation.

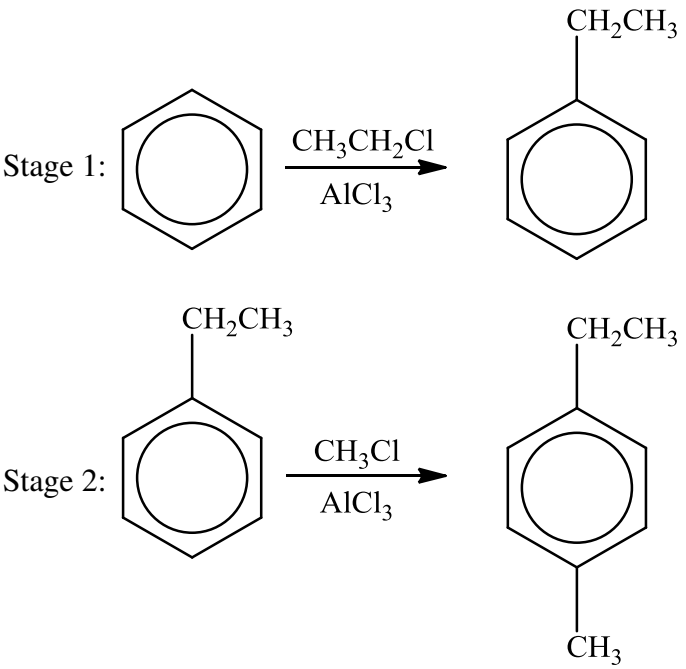
if electrophile attaches at 3-/*m* position positive charge cannot be localized on carbon bonded directly to methyl group / *OWTTE*; ***[2]***
Accept diagram showing three resonance forms.

(c) structure of methylbenzene/ethylbenzene as intermediate;
chloromethane/CH_3Cl **and** chloroethane/CH_3CH_2Cl as reagents / bromomethane/CH_3Br **and** bromoethane/CH_3CH_2Br as reagents;
Accept in any order.

$AlBr_3$/$AlCl_3$/other Lewis acid catalyst (in both steps);
For example:



OR



[3]

Allow bromo compounds.