M13/4/CHEMI/HP3/ENG/TZ2/XX/M

International Baccalaureate®
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MARKSCHEME

May 2013

CHEMISTRY

Higher Level

Paper 3

24 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

A1. (a) The ratio between the distance moved by the spot and the distance moved by the solvent front / *OWTTE*; ***[1]***
Accept this expressed as a correct equation.

(b) R_f value depends on the intermolecular forces that the component has with the mobile phase compared to the stationary phase / relative attraction of the component to mobile phase compared to the stationary phase / partition of the component between the mobile phase and the stationary phase / *OWTTE*;
if polarity of the solvents is different the intermolecular forces/attraction to mobile phase/partition will be different / *OWTTE*; ***[2]***
Accept "Components have different solubilities in different solvents" / OWTTE.

(c) (viewing under) ultraviolet/UV light;
(staining with) a dye/ninhydrin/potassium manganate(VII);
(exposing to) iodine (vapour); ***[2 max]***
Accept "staining with a developing (re)agent".
Do not accept just staining.

A2. (a) (i) ensures that only light with a single/particular/narrow range of wavelength/ frequency is passed through; ***[1]***
Accept "light of only one colour".

(ii) ensures that the beam of (monochromatic) radiation is (alternatively) passed through the sample **and** the reference; ***[1]***
Accept "splits/deflects the beam into two beams".

(iii) converts light/radiation into an electrical current/signal; ***[1]***
Accept "detects the radiation".

(b) (i) (C=C) bond vibrates;
Accept stretch/bend.

(vibration) must involve a change in dipole moment/polarity; ***[2]***

(ii) (energy/frequency of the C=C bond vibration) would depend on groups attached/rest of the molecule / *OWTTE*; ***[1]***

A3. (a) colour due to electrons absorbing energy when they are promoted to a higher energy level / colour observed/transmitted is complementary colour to colour of light absorbed;
pigments all contain much conjugation/delocalization/alternate C–C single and C=C double bonds/ which absorbs light of lower energy/frequency in visible region;
preservatives show little conjugation so absorb light of higher energy/frequency in ultraviolet region; ***[3]***
*Award **[1 max]** for "pigments have greater conjugation/delocalization than preservatives".*

(b) increased conjugation/delocalization (due to removal of H^+ from OH group on benzene ring) / light of lower frequency/longer wavelength absorbed; ***[1]***

A4. (a)

Peak	Hydrogen atom responsible
A	7;
B	4
C	5;
D	3;
E	2;
F	6;
G	1;

[6]

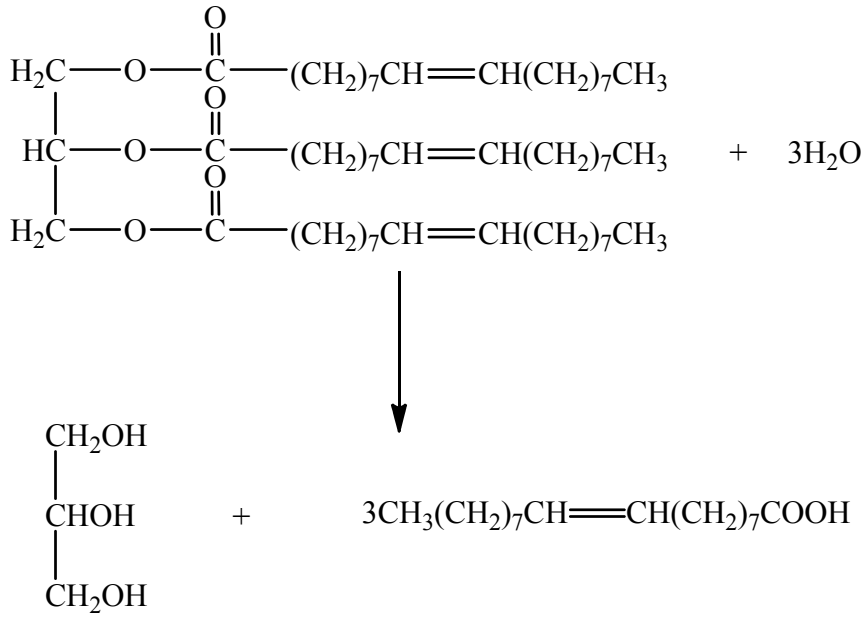
(b) (i) two/2; ***[1]***

(ii) both are singlets / *OWTTE*; ***[1]***

(iii) aspirin will have two (sharp) peaks / wider/greater absorption (due to two C=O groups);
ibuprofen will have one (sharp) peak / narrower/less absorption (due to one C=O group); ***[2]***

Option B — Human biochemistry

B1. (a) (i)



correct structure for triglyceride;
correct structures for products;
correct balancing; ***[3]***

Mark for balancing can only be awarded if reactants and products are correct.
*Accept more condensed structural formula, but ester group must be the correct way round (glycerol–OOC–R or glycerol–O–CO–R, **not** glycerol–COO–R).*
Do not penalize minor errors in the hydrocarbon chain or in the use of R.

(ii) 100 g of oleic acid reacts with $\frac{253.8\times100}{282.52}$ (g) of I_2 ;

Do not penalize use of integer values for M_r.

hence iodine number is 89.9; ***[2]***

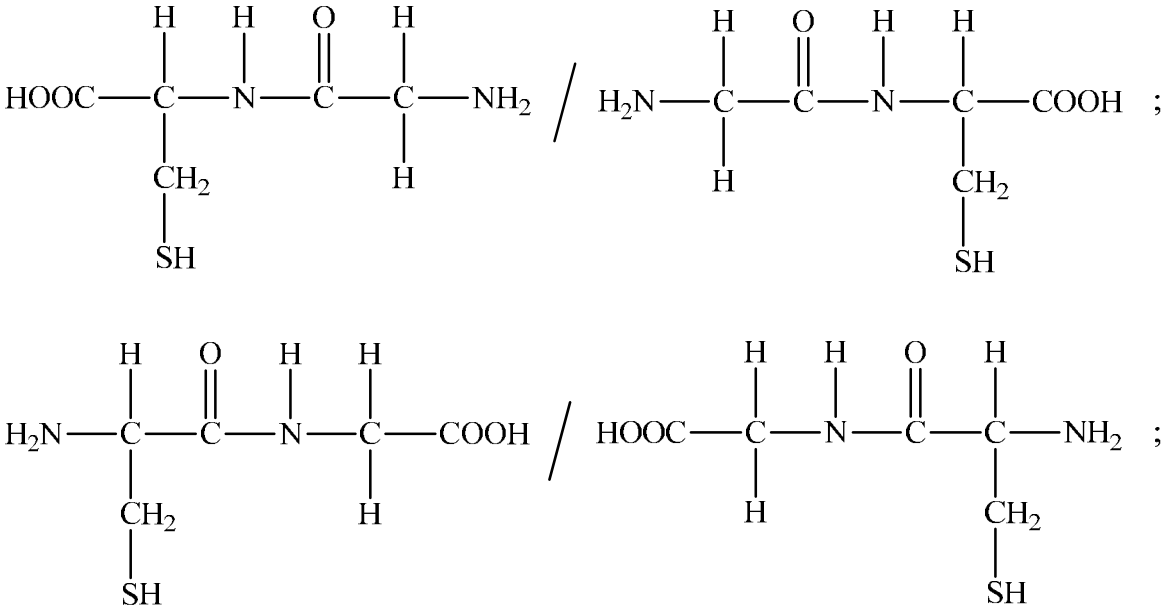
Accept answers between 89.7 and 90.
*Award **[2]** for for correct answer.*
*Award **[1]** for an iodine number between 44.8 and 45.0 if monatomic iodine is assumed.*
*Award **[1]** for an iodine number between 0.897 and 0.900 if 1 g of oleic acid assumed.*
*Award **[1]** for an iodine number between 111 and 112 – mass of I_2 reacting with 100 g of oleic acid.*

(b) (i) in linoleic acid, presence of C=C/double bond/unsaturation prevents close packing/leads to kinks/bends in chain;
*Do **not** allow mark without reference to C=C/double bond/unsaturation.*

hence weaker van der Waals'/London/dispersion forces between molecules; ***[2]***
Accept opposite statements for stearic acid but must point out that this is because it does not have a C=C/double bond/unsaturation.

(ii) cannot be synthesized by body; ***[1]***
Accept specific uses such as lowers LDL cholesterol level, increases HDL cholesterol level or lowers risk of heart disease.
*Do **not** accept just "lowers cholesterol level".*

B2. (a)



;

;

[2]

Accept condensed versions of structures such as –NH–CO–CH_2– / –HN–CO–CH_2–
Penalise repeated minor errors, such as incorrect representation of peptide bond (–COHN–/–NHOC–) once only.
*Award **[1]** for a correct peptide link if the rest of the structure is incorrect.*

(b) (i) sample of amino acids/mixture placed/spotted on gel/ polyacrylamide/ PAGE/paper;
buffer solution / solution of known pH;
(high) potential (difference)/electric field/voltage applied / + and – electrodes/ anode and cathode connected;
Accept current/electricity passed through.

different amino acids move different rates/distances according to their charge/isoelectric point / amino acids move towards oppositely charged electrode / *OWTTE*;
spray/develop with ninhydrin/organic dye/ detect by staining/fluorescence under UV light;
measure distance travelled and compare with standards/isoelectric points; ***[3 max]***
*Award **[1 max]** for the statement "different amino-acids move to different extents".*

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

B3. (a) (i)

	Products formed	Redox nature of the pyruvate ion reaction (oxidation or reduction)
Aerobic respiration	CO_2 **and** H_2O	oxidation
Anaerobic respiration	Lactate/$CH_3CH(OH)COO^-$	reduction

[3]

*Award **[3]** for 4 correct answers.*
*Award **[2]** for 2/3 correct answers.*
*Award **[1]** for 1 correct answer.*
Accept lactic acid/$C_3H_6O_3$.

(ii) aerobic (respiration); ***[1]***

(b) (i) (V_{max}:) $7.75 - 7.85\ (\text{mmol dm}^{-3}\text{s}^{-1})$;
(K_m:) $0.12 - 0.14\ (\text{mmol dm}^{-3})$; ***[2]***
Accept 7.8 for V_{max}.

(ii) hexokinase/enzyme (with a low K_m) has a high affinity for glucose/ substrate / hexokinase/enzyme is saturated with substrate / hexokinase/ enzyme reacts quickly to form an ES complex which breaks down rapidly;
Do not accept strong binding/bonding between enzyme and substrate.

hence needs a lower concentration of glucose/substrate to achieve V_{max} / a fast reaction occurs even when substrate concentration is low; ***[2]***
Accept "enzyme is efficient even at low substrate concentration".

(iii) *First mark:*
K_m increases;

Any two for final two marks:
inhibitor has similar structure to that of substrate;
hence inhibitor occupies/fits same active sites;
inhibitor does not affect V_{max};
substrate must wait until the inhibitor leaves the active site;
reaction slows down/rate decreases; ***[3 max]***

Option C — Chemistry in industry and technology

C1. (a) (i) (bauxite) is reacted with (concentrated) sodium hydroxide/NaOH (solution at high temperature);
forms sodium aluminate / $Al(OH)_3 + OH^- \rightarrow Al(OH)_4^-$;
Accept both ionic and non-ionic equations and different, correct representations of the aluminate ion ($Al(OH)_4^-$, AlO_2^-).

solution is filtered / insoluble impurities removed (by filtration);
reaction reversed by cooling / diluting solution / adding water;
Accept passing CO_2 through the solution.

mixture seeded with alumina crystals;
pure hydroxide precipitated / $Al(OH)_4^- \rightarrow Al(OH)_3 + OH^-$;
Accept both ionic and non-ionic equations and different, correct representations of the aluminate ion ($Al(OH)_4^-$, AlO_2^-).
(pure) $Al(OH)_3$ heated / $2Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O$; ***[3 max]***
*Award **[1 max]** for "Alumina is soluble in alkali, but impurities are not" / OWTTE.*
Ignore state symbols.

(ii) melting point of the cryolite solution is much lower than the melting point of alumina/Al_2O_3 / it lowers the melting point (of the mixture); ***[1]***
*Do **not** allow lowers melting point of aluminium.*
*Do **not** allow lowers required/operating temperature.*
Accept improves conductivity of the electrolyte/aluminium oxide.

(iii) *Positive electrode (anode)*:
$2O^{2-} \rightarrow O_2 + 4e^-$ / $O^{2-} \rightarrow \frac{1}{2}O_2 + 2e^-$ / $C + 2O^{2-} \rightarrow CO_2 + 4e^-$;

Negative electrode (cathode):
$Al^{3+} + 3e^- \rightarrow Al$; ***[2]***
Allow e instead of e^-.
Accept multiples of the correct equations, such as $2Al^{3+} + 6e^- \rightarrow 2Al$.
*Award **[1 max]** if correct equations but at wrong electrodes.*
Ignore state symbols.

(b) by reduction with a more reactive metal/metal above Al in electrochemical series/ECS/reactivity series / *OWTTE*; ***[1]***
Accept equations for displacement reactions of Al_2O_3 with more reactive metals.

(c) graphite/carbon electrodes converted/oxidized (into CO_2);
the fossil fuels used to provide energy/transport (produce CO_2); ***[2]***

C2. (a) homogeneous catalyst is in the same phase/state as the reactants **and** heterogeneous is in a different phase/state to the reactants; ***[1]***

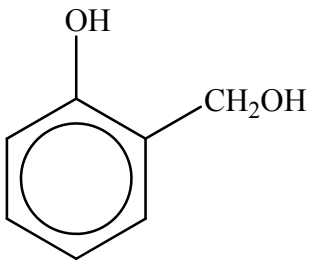
(b) *Advantage*:
all catalyst exposed to reactants / does not depend on surface area / react more rapidly / *OWTTE*;

Disadvantage:
difficult to remove from products; ***[2]***
Accept "Cannot always be used at high temperature".
Apply ECF if C2. (a) the wrong way round.

(c) amount of reactant converted to product per amount of catalyst;
Accept efficiency / conversion rate.

ability to work under different/a range of conditions;
toxicity / environmental/health impact;
catalytic poisoning / active sites become blocked;
lifetime of catalyst;
ease of removal; ***[3 max]***

C3. (a) (i)



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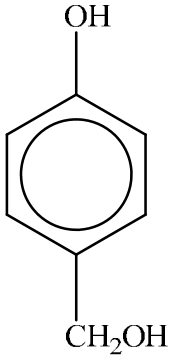
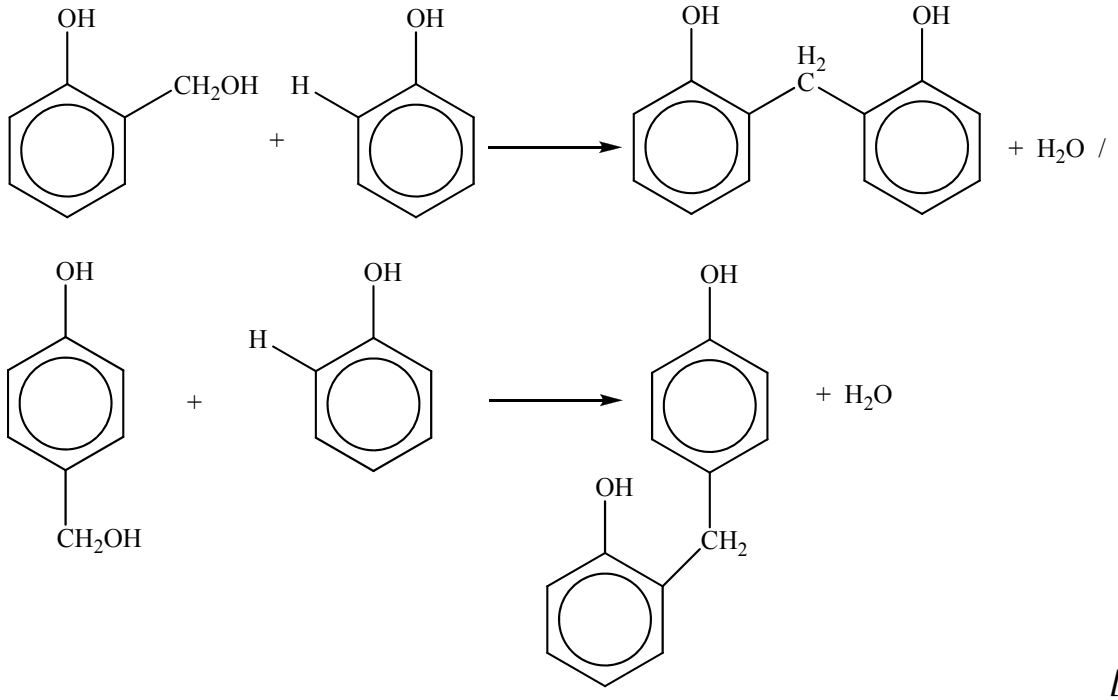


;

[2]

(ii)



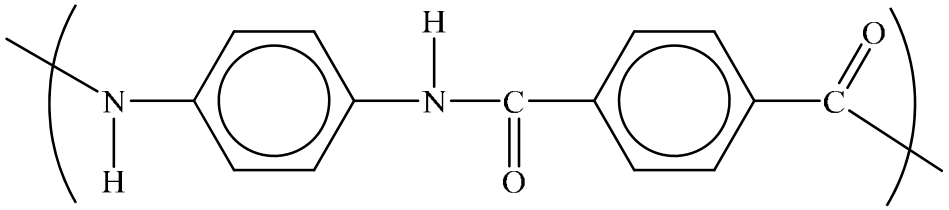
[2]

*Award **[1]** for correct structural formula of organic product.*
*Award **[1]** for H_2O.*

If the overall equation for M1 is incorrect, only award M2 for H_2O if the reaction is clearly shown to be a condensation process.

(iii) covalent bonds form;
between the chains built up by 2- and 4-substituted phenols; ***[2]***

(b) (i)



[2]

*Award **[1]** for correct showing of amide linkage.*
*Award **[1]** for remainder of structure correct.*
Accept H and O both up or both down or accept –NH–CO– but do not accept –N–H–CO–.
Brackets not necessary to gain marks.

(ii) the δ^-/lone pair on the O of the C=O and the δ^+ on the H of the N–H / the polarity of the C=O and the N–H bonds;
Accept N-H of one chain and C=O of adjacent chain or NH_2 group of one chain with C=O group of another chain.

(form) hydrogen bonds / *OWTTE*; ***[2]***
Accept suitable diagram.

Option D — Medicines and drugs

D1. (a) ester; ***[1]***
Accept ethanoate/acetate.
*Do **not** accept formula.*

(b) *Aspirin*:
Intercepts pain stimulus at source / blocks/interferes with production of substances/ prostaglandins that cause pain/swelling/fever / *OWTTE*;

Diamorphine:
(temporarily) bonds to/blocks/interferes with receptor sites/synapses in the brain / prevent transmission of pain impulses (without depressing central nervous system/CNS) / *OWTTE*; ***[2]***
*Award **[1 max]** if answer states that mild analgesic acts at source and strong analgesics act in the brain/CNS.*

(c) prevent stroke/heart attack/disease / thin blood / reduces risk of blood clots / anti-inflammatory; ***[1]***

(d) *Advantage*:
stronger pain killer / lower dose required / quicker acting;

Disadvantage:
more addictive / easier to build up tolerance and exceed lethal dose / smaller therapeutic window/index / *OWTTE*; ***[2]***

D2. (a) *Moderate doses*:
induce sedation / slow down mental activity / reduce anxiety / lower heart rate / relax muscles / vasodilation;
Accept euphoria / reduced inhibitions.

Higher doses:
induce sleep / loss of consciousness / induce coma / cause death; ***[2]***
Accept alters perception / slurred speech / staggering / loss of balance / intoxication.

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

(ii) ethanal/acetaldehyde/CH_3CHO / ethanoic acid/acetic acid/CH_3COOH; ***[1]***
*Do **not** accept aldehyde / carboxylic acid.*

(c) *Blood sample*:
gas(-liquid) chromatography/GLC/GC / high pressure/performance liquid chromatography/HPLC;
No credit for just "chromatography".

column separates the alcohol/ethanol from the other components in the blood / retention time identifies alcohol/ethanol / (the amount of alcohol/ethanol in the blood is) compared with a known sample / by measuring the area under the eluted peaks / *OWTTE*;

Intoximeter:
infrared spectroscopy/infrared light passed through;
the absorption of the C–H/C–O bond is measured (and compared with a calibrated sample) / *OWTTE*;

OR

fuel cell;
an electric current/voltage is generated (proportional to the concentration of alcohol/ethanol in the breath) / *OWTTE*; ***[4]***

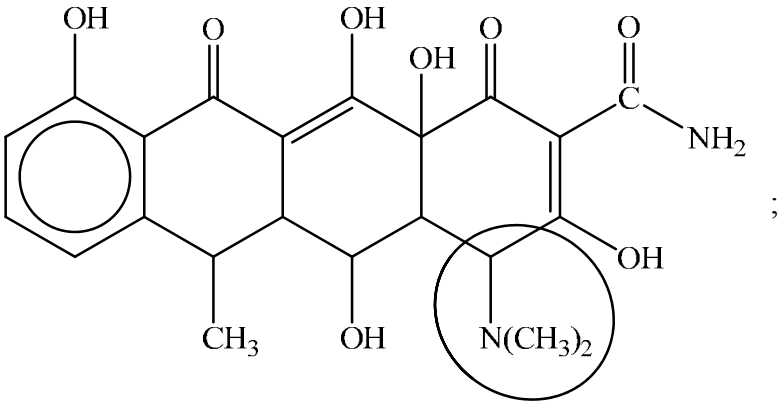
(d) enhances the effect/causes a stronger/different effect of another drug (present in the body at the same time); ***[1]***

D3. (a) (i) penicillin(s)/antibacterial(s)/antibiotic; ***[1]***

(ii) (β-lactam) ring is strained;
Accept stressed.
sp^3 **and** sp^2 hybridization;
bond angles are 90° / less than 120° and 109.5° / *OWTTE*; ***[2 max]***

(iii) (the sodium salt) makes the penicillin ionic/<u>more</u> polar;
this increases its solubility in water/more concentrated in bloodstream / makes it more able to be absorbed by the body / *OWTTE*; ***[2]***

(b) (i)



;

Circle must go around the N atom (joined to the two CH_3 groups) and not include more than the two CH_3 groups and the carbon atom in the ring directly bonded to it.
Accept a circle around the $–N(CH_3)_2$ without including the carbon atom of the ring.

tertiary; ***[2]***
M2 can only be awarded if M1 is correct.

(ii) react with hydrochloric acid/any other named strong acid / convert the amine group into a salt/ammonium ion/its hydrochloride/any other named product;
Accept amino for amine group.
react with sodium hydroxide/OH^- / convert a phenolic/OH group on the benzene ring/ into a phenoxide ion/sodium salt; ***[1 max]***

(iii) six/6;
The different enantiomers/isomers may have different physiological/ pharmacological effects on the body / one enantiomer benefits the body, the other might not / *OWTTE*;
Accept a specific example such as thalidomide.
Accept one enantiomer could have a toxic effect.
Do not allow just "has different effects". ***[2]***

Option E — Environmental chemistry

E1. (a) (i) acidic/acid-forming pollutants deposited on the Earth's surface/leave the atmosphere / rain/precipitation/deposition that is acidic/with a $pH < 5.6$; ***[1]***
Award mark if two specific examples are given.
Accept acid rain.

(ii) $SO_2/SO_3/NO_2$;
Allow names of oxides. Do not allow NO_x.
Accept NO, but for second mark $2NO + O_2 \rightarrow 2NO_2$ must also be included.

$SO_2 + H_2O \rightarrow H_2SO_3$ / $SO_3 + H_2O \rightarrow H_2SO_4$ /
$2SO_2 + O_2 + 2H_2O \rightarrow 2H_2SO_4$ / $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$ /
$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$; ***[2]***
Do not allow ECF for equation.

(iii) addition of lime/$Ca(OH)_2$/limestone/$CaCO_3$; ***[1]***
Accept "adding alkali/base" or "neutralizing acidity".

(b) *For SO_2/SO_3*:
remove S from fossil fuels;
alkaline scrubbing;
(limestone-based) fluidized bed combustion;
flue gas desulfurization in coal-burning power stations;
use oxide ores rather than sulphide ores;

For NO_2:
control of fuel/air ratio;
recirculation of exhaust fumes;
catalytic converter;
thermal exhaust reactor; ***[2 max]***

For either:
Allow ECF for incorrect (a) (ii).
Accept "reducing energy consumption/use of powered transport" / OWTTE for either.
Accept "use renewable energy sources/hydro/solar/tidal/wind" / OWTTE for either.

E2. (a) *Formation*:
$O_2 \rightarrow 2O\bullet$ **and** $O\bullet + O_2 \rightarrow O_3$;

Depletion:
$O_3 \rightarrow O_2 + O\bullet$ **and** $O\bullet + O_3 \rightarrow 2O_2$; ***[2]***

Do not accept $O\bullet + O\bullet \rightarrow O_2$.

No penalty for missing radical symbols.
*Award **[1 max]** for one correct formation and one correct depletion equation.*
*Do **not** penalise failure to mention UV light.*

(b) (i) CFCs have a low reactivity/strong bonds/are highly stable;
CFCs/radicals they produce/ $Cl\bullet$ have high residual time in atmosphere;
some (developing) countries still producing/consuming CFCs / slower phase-out of CFCs;
harmful CFCs are still present in expanded polystyrene and old refrigerators and have yet to leak into the atmosphere;
slow mixing between lower atmosphere/troposphere and upper atmosphere/stratosphere; ***[1 max]***

(ii) *Advantage*: ***[1 max]***
do not damage the ozone layer;
decompose less readily (than CFCs);
cheaper than CFCs;

Disadvantages:
flammable;
both contribute to global warming/greenhouse gases/absorb IR radiation; ***[3 max]***

E3. (a) valley location/bowl-shaped;
no wind/limited air circulation;
temperature inversion / layer of warmer air over cold air; ***[3]***

(b) (i) aldehyde/R–CHO;
PANs/ $RCOOONO_2$;
nitric acid/HNO_3;
organic peroxides; ***[2max]***

(ii) *Aldehyde*:
$R{-}CH_2O\bullet + O_2 \rightarrow R{-}CHO + HO_2\bullet$;

PAN:
$RCO_3\bullet + NO_2 \rightarrow RCO_3NO_2$;

Nitric acid:
$HO\bullet + NO_2 \rightarrow HNO_3$; ***[2 max]***

Accept any other correct equations.
No penalty for missing radical symbols.
No ecf for incorrect secondary pollutants in(b)(i).

E4. (a) $Hg^{2+}(aq) + S^{2-}(aq) \rightarrow HgS(s)$ / $H_2S(g) + Hg^{2+}(aq) \rightarrow HgS(s) + 2H^+(aq)$ / $H_2S(aq) + Hg^{2+}(aq) \rightarrow HgS(s) + 2H^+(aq)$;
correctly balanced equation;
correct state symbols; ***[2]***
Neither mark can be awarded for an incorrect equation.

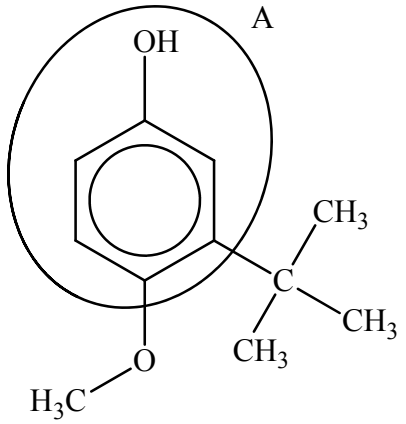
(b) (i) $(K_{sp} =)[Cd^{2+}(aq)][S^{2-}(aq)]$;
$[Cd^{2+}(aq)] = 2.83 \times 10^{-14} (mol\,dm^{-3})$; ***[2]***
*Award **[2]** for correct final answer.*
Ignore state symbols.

(ii) increase in $[S^{2-}(aq)]$;
causes CdS precipitate to form/equilibrium shifts to form more CdS/common ion effect / *OWTTE*; ***[2]***

Option F — Food chemistry

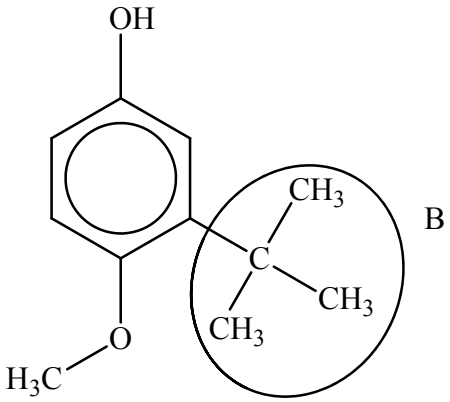
F1. (a) a substance which slows/delays/prevents the onset of oxidation (of food); ***[1]***

(b) (i)



correct circle around the phenolic group; ***[1]***
Accept a circle around –OH alone or around –COH.

(ii)



correct circle around the tertiary butyl group; ***[1]***

(c) β-carotene/carotenes;
vitamin C/ascorbic acid;
vitamin E/tocopherols;
selenium; ***[2 max]***

(d) (i) *Free-radical inhibitors*:
Interrupt/inhibit free radical chain mechanism/free radical formation / interrupt/inhibit initiation/propagation step (in auto-oxidation) / form stable and less reactive free radicals / *OWTTE*;

Chelating agents:
reduce concentration of free (transition) metal ions in solution / form stable complexes with (transition) metal ions / act as ligands forming (dative covalent) bonds with metal ions;

Reducing agents:
electron donors / remove/reduce concentration of oxygen / become oxidised (instead of the food); ***[3]***

(ii) tea;
rosemary;
ground mustard; ***[1 max]***
Accept specific natural chelating agents which are found in the sources above such as catechins (from tea), rosemarinic acid (rosemary) and phytic acid (from mustard).

F2. (a) temperature (changes);
light;
pH (change);
presence of metal ions;
oxidation/reduction; ***[2 max]***

(b) (i) HCO_3^- produces a (slightly) alkaline/basic pH / pH range 7.5–9 / *OWTTE*; ***[1]***
Accept "buffers the solution".

(ii) Mg^{2+}/magnesium (ion) displaced by (two) H^+/hydrogen (ions); ***[1]***
Accept Mg^{2+}/magnesium (ion) is released.

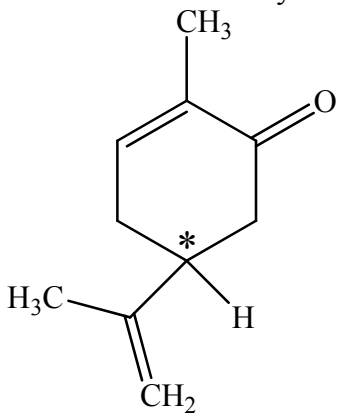
(iii) pheophytin (complex); ***[1]***

(c) (NH_2 /amino group of) amino acid/peptide/protein;
(carbonyl group of) reducing sugar/glucose;
react by condensation;
lysine in particular causes browning colour; ***[3 max]***

F3. *Benefits*: ***[2 max]***
enhanced taste/quality/appearance;
longer shelf life;
reduced maturation time;
improved tolerance of drought / marginal conditions / rainfall/temperature/nutrient levels;
increase in yield/productivity/feed efficiency;
development of crops with greater amounts of nutrients/micronutrients;
more resistant to herbicides and insecticides / permit the use of more environmentally friendly herbicides and insecticides;
increased resistance to pests/disease / improved animal health;

Concerns: ***[2 max]***
links to increased allergies (for people involved in GM food processing);
risk of changing the composition of a balanced diet/altered nutritional quality of food;
pollen from GM crops may contaminate normal crops with unknown effects;
uncertainties about long-term health effects of genetic modification of food; ***[4 max]***

F4. (a) chiral carbon correctly identified;



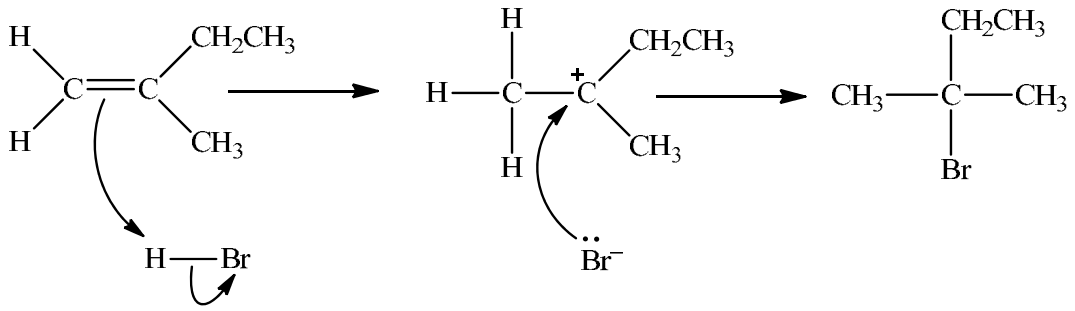
[1]

(b) clockwise rotation of plane-polarized light / dextrorotatory / rotation of plane-polarized light to right; ***[1]***
Do not accept reflect or bend.
Accept twists or spins.

(c) S isomer;
priority groups (according to atomic number) ordered anti-clockwise/ counter-clockwise (according to Cahn-Ingold-Prelog/CIP convention) / priority decreases in the anti-clockwise/counter-clockwise direction; ***[2]***
Do not award mark if reference is made to molecular/molar mass.

Option G — Further organic chemistry

G1. (a) (i) electrophilic addition; ***[1]***

(ii) 

curly arrow from C=C to H of H–Br **and** curly arrow showing Br leaving;
correct carbocation representation;
curly arrow from lone pair/negative charge on Br^- to C^+; ***[3]***

(iii) 2-bromo-2-methylbutane involves the formation of an intermediate tertiary carbocation;
this is more stable than the primary carbocation intermediate that would be formed if the product was 1-bromo-2-methylbutane;
Accept argument based on low stability of primary carbocation.

the increased positive inductive effect of the extra –R groups increases the stability of the intermediate / *OWTTE*; ***[2 max]***
*Do **not** award marks for quoting Markovnikov's rule without any explanation.*

(b) react with (warm, aqueous) sodium hydroxide solution / OH^-(aq); ***[1]***
*Do **not** accept answers, such as NaOH, that do not refer to water/solution.*

(c) magnesium/Mg;
non-polar solvent/ether/diethyl ether/ethoxyethane / dry/absence of water; ***[2]***

G2. (a) all C–C bond lengths/strengths are the same/between the different lengths/strengths for C–C single bond and a C=C double bond / *OWTTE*;
Do not accept "bonds are the same" without any qualification.

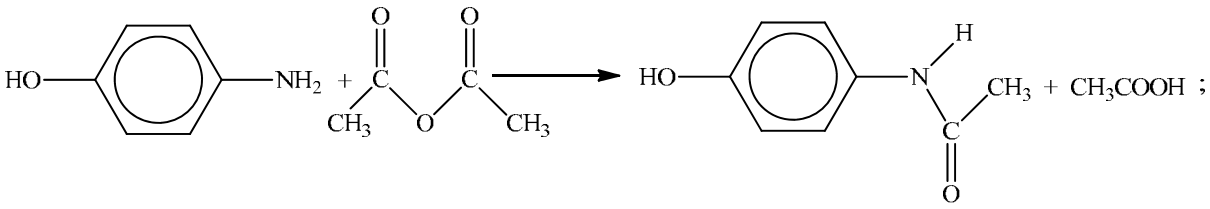
only one 1,2-disubstituted isomer exists whereas there would be two if there were alternate double and single bonds / only three disubstituted benzene compounds rather than four / *OWTTE*;
benzene (mainly) undergoes (electrophilic) substitution reactions rather than addition reactions (which would be expected if it contains C=C double bonds) / *OWTTE*;
Accept does not undergo addition reactions / decolourize bromine water.

the enthalpy change of hydrogenation/combustion is less exothermic than would be expected if benzene contained three double bonds/not 3 times that of cyclohexene / the enthalpy change of formation is less endothermic / *OWTTE*; ***[3 max]***

(b) *Iodobenzene:*
does not (readily) react;
the C–I bond is stronger due to delocalization of (one of) the non-bonding pair of electrons on the I atom with the benzene pi electrons / the pi electrons on the benzene ring repel the OH^-/nucleophile making it less likely to react with the carbon atom attached to the I atom / the lone pair on the I atom in iodobenzene is delocalized into the ring, considerably reducing the polarity of the C–I bond / benzene ring prevents the nucleophile attacking from the opposite direction to the C–I bond;
Accept "steric hindrance".

(Iodomethyl)benzene:
reacts (readily);
the OH^-/nucleophile attacks the δ^+ C atom attached to the I atom as the benzene ring has little effect / *OWTTE*; ***[4]***
Accept "reacts by nucleophilic substitution/S_N2 mechanism".
Accept the opposite any of the reasons given above for lack of iodobenzene reactivity, ***other than*** *the one used in the answer to the first part.*

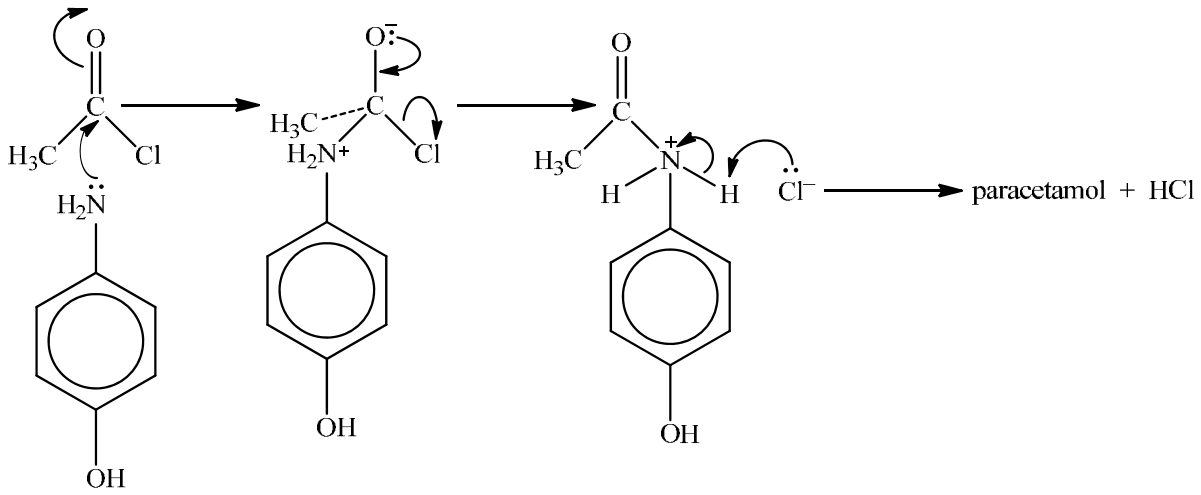
G3. (a)



Accept condensed structural formula eg, $HO{-}C_6H_4{-}NH_2$ and $(CH_3CO)_2O$.

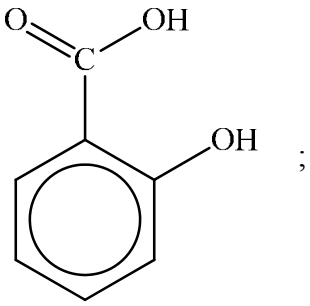
ethanoic acid/acetic acid; ***[2]***

(b)



curly arrow from N on 4-aminophenol to C atom **and** curly arrow from C=O double bond to O;
correct intermediate showing negative charge on O^- **and** positive on N^+;
curly arrow from O to C–O bond **and** curly arrow from C–Cl to Cl;
curly arrow from NH bond to N^+; ***[3 max]***

(c)



;

[1]

Accept –COOH instead of the expanded carboxyl group in the structure;

(d) $Br{-}CH_2{-}CH(CH_3)_2$ / 1-bromo-2-methylpropane;
Accept chloro or iodo-equivalent.

halogen carrier/ $AlCl_3/AlBr_3/AlI_3/Fe/FeCl_3$ / non-polar solvent/ether/ethoxyethane / heat;
electrophilic substitution; ***[3]***
Accept "the carbocation intermediate may convert to the more stable tertiary form (to give $C_6H_5{-}C(CH_3)_3$)".