N12/4/CHEMI/HP3/ENG/TZ0/XX/M

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# MARKSCHEME

## November 2012

## CHEMISTRY

## Higher Level

## Paper 3

23 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) *Monochromator:*
allows only a narrow band/one frequency/wavelength/wavenumber (of IR radiation) to pass through;

*Splitter:*
splits the (infrared) light into two beams (with the same wavelength);

*Reference:*
absorbance/transmittance (of the reference) compared with/subtracted from absorbance/transmittance of sample / (the reference is) used to set the baseline / compare with sample/current / compensation for solvent / *OWTTE*; ***[3]***

(b) detector/sensor/photodiode/photomultiplier; ***[1]***

**A2.** (a) *Qualitative:*
identification of an unknown substance / identify presence/verify purity of an individual substance / determination of the qualitative composition of a mixture / *OWTTE*;

*Quantitative:*
measurement of the concentration/amount/level of a substance in a solution/ mixture/biological material / determination of the ratio of components/percentage composition of a mixture / *OWTTE*; ***[2]***
*Accept other general or specific uses.*

(b) components dissolve in solvent/mobile phase;
components adsorb onto stationary phase/$SiO_2$;
components have different affinities for stationary phase / different solubility in mobile phase;

distribution/partition between a stationary phase and a mobile phase;
components move only when they are in the mobile phase / components don't move when they are in/on the stationary phase / *OWTTE*;
better soluble/less adsorbed components elute earlier / less soluble/better adsorbed component elute later / *OWTTE*; ***[4 max]***
*Accept silica/alumina etc. instead of stationary phase.*

**A3.** (a)

| Chemical shift / ppm | Number of hydrogen atoms |
|---|---|
| 1.0–1.1 | 3 |
| 2.15 | 3; |
| 2.4–2.5 | 2; |

***[2]***

(b)

| Chemical shift / ppm | Splitting pattern | Number of adjacent hydrogen atoms |
|---|---|---|
| 1.0–1.1 | triplet | 2 |
| 2.15 | singlet | 0 |
| 2.4–2.5 | quartet | 3 |

***[2]***

*Award **[1]** for both splitting patterns correct.*
*Award **[1]** for both number of adjacent hydrogen atoms correct.*

(c) $CH_3COCH_2CH_3$; ***[1]***

*Accept more detailed formula*.

**A4.** (a) uses no ionizing radiation / uses low-energy radio waves / radio waves safer than x-rays / *OWTTE*; ***[1]***

*Accept "does not damage body tissue".*

(b) MRI is (usually) a proton NMR/$^1$H NMR;
(the states of) protons/hydrogen atoms in water/lipids/carbohydrates/proteins/ different (chemical) environments are detected;
different organs have different water concentration;
(strong) magnetic field **and** radio waves/frequency are used;
(by focusing the scanner on different parts of the body) three-dimensional/3-D images of (organs in) the body are produced / *OWTTE*; ***[3 max]***

**A5.** (a) increase in oxidation state causes greater splitting;
change from $H_2O$ to $NH_3$ causes greater splitting;
the greater the splitting, the higher the frequency (of absorbed light);
(complexes of) Cr(III) absorb higher-frequency light than (complexes of) Cr(II) /
(complexes with) $NH_3$ absorb higher-frequency light than (complexes with) $H_2O$; ***[3 max]***
*Allow converse statements and OWTTE throughout.*

(b) *Analysed solution*:
$1.43 \times 10^{-2} (\text{mol dm}^{-3})$;
*Accept any value from* $1.40 \times 10^{-2}$ *to* $1.46 \times 10^{-2}$.

*Sample*:
$0.286 \text{ mol dm}^{-3}$; ***[2]***
*Accept any value from 0.280 to 0.292.*

(c) tetracene **and** greater number of conjugated (double) bonds/larger delocalized system / *OWTTE*; ***[1]***

**Option B — Human biochemistry**

**B1.** (a) (plant) material/cellulose which is (mainly) indigestible/not hydrolysed (by human enzymes) / *OWTTE*; ***[1]***

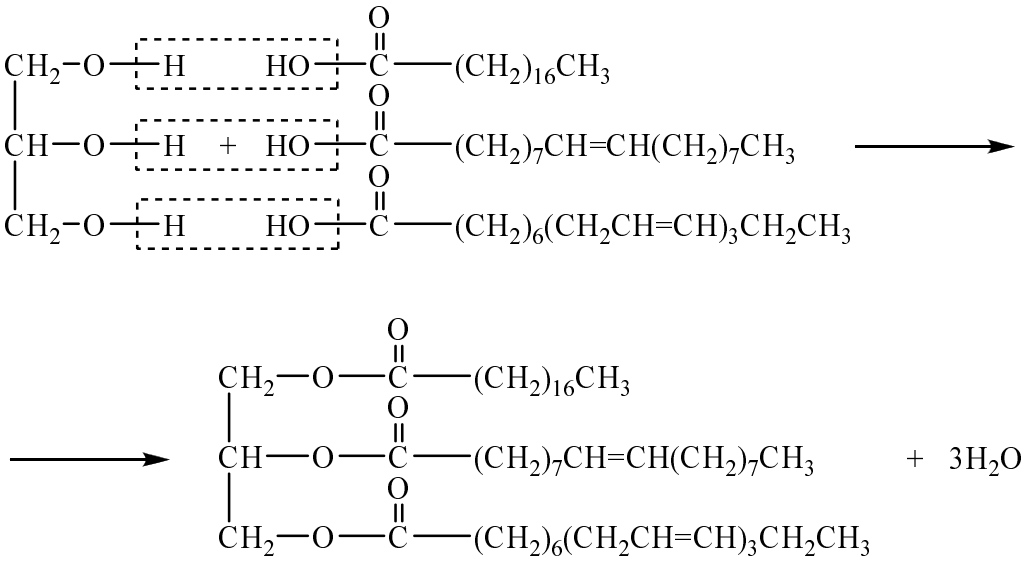
(b) provides bulk to the diet;
reduces appetite/intake of excessive food / prevents obesity;
prevents constipation / facilitates regular elimination / accelerates passage of food through digestive system;
regulates blood sugar / reduces the risk of diabetes;
reduces risk of hemorrhoids/bleeding of rectum wall/Crohn's disease/bowel cancer/disorders/IBS; ***[3 max]***
*Accept other examples.*

**B2.** (a) *Saturated*:
octanoic / $C_7H_{15}COOH/CH_3(CH_2)_6COOH$ /
lauric / $C_{11}H_{23}COOH/CH_3(CH_2)_{10}COOH$ /
palmitic / $C_{15}H_{31}COOH/CH_3(CH_2)_{14}COOH$ /
stearic / $C_{17}H_{35}COOH/CH_3(CH_2)_{16}COOH$ ;

*Mono-unsaturated*:
oleic / $C_{17}H_{33}COOH/CH_3(CH_2)_7CH=CH(CH_2)_7COOH$ ;

*Poly-unsaturated*:
linoleic / $C_{17}H_{31}COOH/CH_3(CH_2)_4(CH=CHCH_2)_2(CH_2)_6COOH$ /
linolenic / $C_{17}H_{29}COOH/CH_3CH_2(CH=CHCH_2)_3(CH_2)_6COOH$ ; ***[3]***
*Accept name or formula.*
*Accept other correct examples of fatty acids.*
*Accept systematic names instead of trivial names.*

(b)

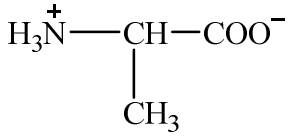


*This scheme is only one of many possible examples.*
the release of <u>three</u> molecules of water;
correct structure of all three ester groups; ***[2]***
*Accept more condensed structural formulas.*
*Ester group must be written correctly, glycerol–OOC–R (not glycerol–COO–R).*
*Do not penalize for minor mistakes in the hydrocarbon chains or the use of R.*

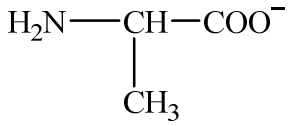
(c) (i) phospholipids **and** steroids; ***[1]***
*Do not accept cholesterol/other specific examples*.

(ii) all three types of lipids are (predominantly) hydrophobic/non-polar/consist mostly of hydrocarbon fragments;
triglycerides and (most) phospholipids contain (a fragment of) glycerol;
steroids are (poly)cyclic compounds/contain (several) rings;
phospholipids contain phosphate (group);
triglycerides and phospholipids are esters; ***[2 max]***
*Allow phosphoric acid/phosphorus instead of phosphate in phospholipids*.
*Allow cholesterol is (poly)cyclic compound/contains (several) rings as ECF from (i).*

**B3.** (a) *Zwitterion*:


;

*Anionic*:


;

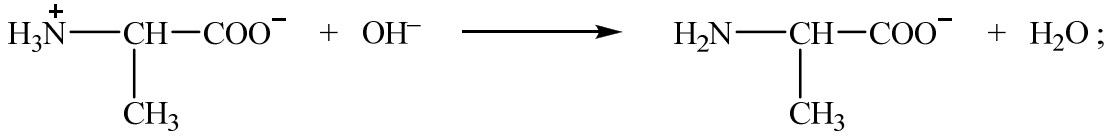
***[2]***

*If a different 2-amino acid is used instead of alanine, penalize it once only in the paper.*

(b) *Reaction with a strong acid:*


;

*Reaction with a strong base:*


;

***[2]***

*Accept molecular formulas of a strong acid/base and the salt of amino acid.*
*Do not award marks for structures/equations with incorrect or missing charges.*

(c) primary structure the sequence/order of amino acids **and** secondary structure regular/repeating folding/coiling of (amino acid) chains/α-helix/β-pleated sheet;
primary structure covalent/peptide bonds **and** secondary structure hydrogen bonds;
*Accept an annotated drawing or diagram for M1.*

**OR**

primary structure the sequence/order of amino acids **and** covalent/peptide bonds;
secondary structure regular/repeating folding/coiling of (amino acid) chains **and** hydrogen bonds; ***[2]***

**B4.** ribose in RNA **and** deoxyribose in DNA;
uracil in RNA **and** thymine in DNA;
RNA single-stranded **and** DNA double-stranded/double helix; ***[3]***
*Accept suitable drawings/diagrams.*

**B5.** $V_{max} = 0.39$;
*Accept any value from 0.385 to 0.395.*

$K_m = 1.3$;
*Accept any value from 1.1 to 1.3.*

$V_{max}$: maximum possible reaction rate for certain enzyme concentration/reaction rate when all enzyme sites are saturated by substrate / *OWTTE*;
$K_m$: substrate concentration when $V_0 = \frac{V_{max}}{2}$ / substrate concentration when half of the enzyme sites are saturated / dissociation constant of enzyme–substrate complex/measure of the enzyme affinity for substrate / maximum substrate concentration for the (approximately) first-order reaction / *OWTTE*; ***[4]***

**Option C — Chemistry in industry and technology**

**C1.** (a) iron ore as source of iron;
*Accept named ore e.g. haematite/siderite/$Fe_2O_3$/magnetite/$Fe_3O_4$.*

limestone/$CaCO_3$ to remove (acidic) impurities / formation of slag;
coke/carbon/methane as reducing agent / to provide heat/high temperature;
air/oxygen/methane to form CO for reduction / supply oxygen for combustion of coke; ***[3 max]***
*Do not award mark for methane twice.*
*Award **[1 max]** for identifying three raw materials only without stating purposes.*

(b) $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$;
$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$;
$Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$;
$FeO + CO \rightarrow Fe + CO_2$; ***[2 max]***
*Penalize incorrect balancing of equations once only.*
*Accept any other correct relevant equation.*

(c) $CaO + SiO_2 \rightarrow CaSiO_3$ / $CaO + Al_2O_3 \rightarrow Ca(AlO_2)_2$ /$CaAl_2O_4$; ***[1]***
*Accept any other correct relevant equation.*

(d) reduce the carbon content /heating in an oxygen convertor;
annealing by heating and cooling slowly; ***[2]***

**C2.** *Steam cracking:*
homogeneous;

*Catalytic cracking:*
heterogeneous;

*Hydrocracking:*
heterogeneous; ***[3]***

**C3.** (a) (i) **A** has greater van der Waals/London/dispersion/intermolecular forces than **B**; ***[1]***
*Penalize incorrect forces.*

(ii) molecules are packed closer together in **A** than **B** so **A** is more dense / **B** is less dense; ***[1]***

(iii) **B** is more flexible as the molecules are further apart/able to move past each other; ***[1]***

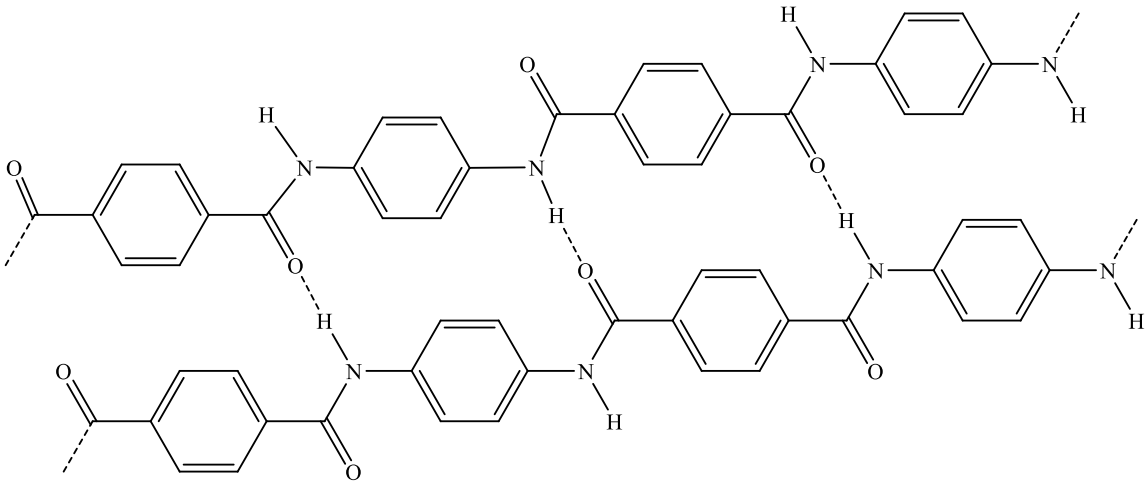
(b) closely packed molecules with crystalline structure;

(plasticizers) separate the PVC molecules/polymer chains / disrupt crystalline structure;
decrease/weaken intermolecular forces/intermolecular dipole-dipole interactions/ van der Waals'/London Dispersion;
*Do not accept mention of H-bonding*
makes it (PVC) softer/more flexible/more easily moulded; ***[3 max]***

**C4.** (a) condensation (polymerization); ***[1]***

(b) (i) hydrogen bonding; ***[1]***

(ii)



dotted lines showing intermolecular forces; ***[1]***

(c) molecules are straight and inflexible/rod-like; ***[1]***

(d) (i) sulfuric acid protonates N and O atoms in the amide groups / hydrolyses/breaks down amide groups;
which weakens/breaks hydrogen bonds between the chains (allowing it to dissolve); ***[2]***

(ii) non-biodegradable;
so would take up space in landfill;
inefficient combustion could lead to the formation of dioxins/pollutants/ toxic compounds; ***[2 max]***

**Option D — Medicines and drugs**

**D1.** (a) drug design/discovery/screening/identifying lead compound;
preparation of analogues through combinatorial chemistry;
characterization of the new compound / in vitro testing / drug formulation/delivery/stability studies;
pre-clinical (toxicology and pharmacokinetics) tests / tests on animals/bacteria/ cell cultures / $LD_{50}$ / *OWTTE*;
clinical tests/tests on humans;
$ED_{50}$ to show improvements over existing drugs / *OWTTE*; ***[3 max]***
*Penalize for incorrect order once only.*

(b) oral – by mouth / swallowing pills/powders / drinking liquids/mixtures / *OWTTE*;
inhalation – administering drugs into respiratory tract / inhaling gases/vapours/ sprays/powders;
rectal – introducing drugs into the rectum/colon via the anus / using suppositories/ enemas;
transdermal – diffusion through the skin/skin patches/ointments/therapeutic baths; ***[2 max]***
*Accept other methods/variations with appropriate descriptions.*
*Award **[1 max]** if only two correct names or two correct descriptions are given.*

(c) irregular/interrupted treatment allows more bacteria to survive (and mutate) / failure to complete full course / *OWTTE*;
surviving bacteria develop/pass on resistance to the drug; ***[2]***
*Do not accept superbugs.*

**D2.** (a) *Aspirin:*
(increased risk of) stomach bleeding;

*Diazepam:*
heavy sedation/unconsciousness/coma / suppresses CNS; ***[2]***

(b) (i) *Dichromate(VI) ions:*
accept electrons **and** (thus) reduced;

*Ethanol:*
loses electrons **and** (thus) oxidized; ***[2]***
*Award **[1 max]** for stating that dichromate is reduced **and** ethanol is oxidized without reference to electrons.*
*No ECF from dichromate to ethanol.*

(ii) ethanol is oxidized by (atmospheric) oxygen;
oxidation at the anode / reduction at the cathode;
electrical current is produced (by the reaction);
the current/anode potential is proportional/related to the ethanol level/ concentration; ***[2 max]***
*Accept emf.*

**D3.** requires qualified personnel;
requires storage space;
expensive;
time-consuming;
limited shelf life of chemicals (some might decompose before the library is created); ***[3 max]***
*Allow other reasonable disadvantages*.

**D4.** (non-charged) carboxylic acids/groups can be converted into more polar salts/ carboxylates;
(non-charged) amines/amino groups can be converted into more polar amines/ ammonium groups;
more polar/charged/ionic substances are more soluble in water/concentrate in the bloodstream; ***[3]***

**D5.** (a) euphoria/altered perception/relaxation;
analgesic/pain-killer; ***[2 max]***
*Allow other valid effects*.

(b) availability of cannabis as a medical drug/pain-killer/analgesic;
recreational use / (arguably, a safer) alternative to tobacco/alcohol/other (illegal) drugs;
reduced costs associated with prosecution of drug users/dealers/producers / additional taxes/jobs / reduced illegal drug/money trafficking;
reduced risk to users (due to better control/availability of pure drug); ***[2 max]***
*Allow other valid arguments.*

(c) increased risk of accidents/crimes (due to euphoria/altered perception of cannabis users);
increased number of drug addicts/medical cost associated with treatment of addicts;
harmful side-effects of THC/cannabis use/smoking in general;
possibility of cannabis users to move to harder drugs; ***[2 max]***
*Allow other valid arguments*.

**Option E — Environmental chemistry**

**E1.** (a) pesticides – farming;
organic matter – sewage / food processing / detergents / oil industry / wood industry;
dioxins – waste incineration/emissions from industry/power plants;
polychlorinated biphenyls/PCBs – (electronic/chemical) industry;
nitrates / $NO_3^-$ – fertilizers/farming;
phosphates / $PO_4^{3-}$ / $HPO_4^{2-}$ / $H_2PO_4^-$ – detergents/fertilizers/farming; ***[2 max]***
*Accept specific applications/processes.*
*Award **[1 max]** for two correct primary pollutants without sources.*

(b) *Primary stage:*
sedimentation/flotation/filtration **and** particulates/solid pollutants/oil/grease;

*Secondary stage:*
aerobic biodegradation/treatment with micro-organisms and oxygen/activated sludge process **and** organic matter/named component of organic matter/ammonia/ nitrogen compounds;

*Tertiary stage:*
biological removal of nitrogen/phosphorus compounds / treatment with chemicals / chemical precipitation / disinfection (with halogens/ozone/UV) **and** ammonia/nitrates/phosphates/heavy metals/micro-organisms/viruses/pathogens; ***[3]***
*Award **[1 max]** if three processes are identified but no substances are given.*
*Award **[2 max]** if the stages are described in incorrect order.*

**E2.** (a)

| Reaction | Environment |
|---|---|
| $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ | aerobic |
| $CH_3COO^- + H_2O \rightarrow CH_4 + HCO_3^-$ | anaerobic |
| $2CH_2O + SO_4^{2-} \rightarrow 2CO_2 + H_2S + 2OH^-$ | anaerobic |
| $2CH_2O + O_2 + 2OH^- \rightarrow 2HCOO^- + 2H_2O$ | aerobic |

***[2]***
*Award **[2]** for all four correct, award **[1]** for two or three correct.*

(b) eutrophication – (unrestricted) growth of plankton/algae/micro-organisms/plants;
thermal pollution – lower solubility of oxygen/$O_2$ in hot water;
decrease in population/extinction of fish/aquatic animals/complex plants / replacement of native species with new (anoxia-tolerant/thermophilic) organisms; ***[3]***

**E3.** landfills require more space/land / are unsightly/ugly;
incineration reduces volume/mass of waste;
landfills require (long-term) site maintenance/need to settle/produce methane;
incineration produces stable residue;
landfills pollute ground water/incineration pollutes atmosphere;
landfills can be expanded easily/incineration plants have limited capacity; ***[3 max]***
*Accept statements of relative cost of landfills and incineration if they are justified with comments about the availability/cost of land.*
*Accept converse statements for M1 and M2.*

**E4.** ammonia neutralizes acids <u>in the atmosphere</u> / ammonium salts are formed <u>in the atmosphere</u>;
$NH_3 + HNO_3 \rightarrow NH_4NO_3$ / $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$;
*Accept reactions of $NH_3$ with $HNO_2$/$H_2SO_3$.*
*Accept acid salts as products.*

salts are washed down with rain/precipitate from the atmosphere;
oxidation/nitrification/acidification of ammonia <u>in the soil</u>/(ground) <u>water</u>;
$NH_4^+ + 2O_2 \rightarrow 2H^+ + NO_3^- + H_2O$; ***[4 max]***
*Accept other balanced equations with $HNO_3$/$HNO_2$/$H^+ + NO_2^-$ as products.*
*Award **[2 max]** if no correct equations are given.*

**E5.** (a) amount/number of equivalents of exchangeable cations/cation sites per 100 g/unit of soil;
clay/aluminosilicates **and** (soil) organic matter/humus; ***[2]***

(b) iron and calcium ions precipitate/reduce availability of phosphates (in soils);
iron is more available in acidic soils/at low pH;

$Fe^{3+} + PO_4^{3-} \rightarrow FePO_4\downarrow$ / $Fe(OH)^{2+} + H_2PO_4^- \rightarrow FePO_4\downarrow + H_2O + H^+$;
calcium is more available in alkaline soils/at high pH;
$3Ca^{2+} + 2PO_4^{3-} \rightarrow Ca_3(PO_4)_2\downarrow$ / $Ca^{2+} + HPO_4^{2-} \rightarrow CaHPO_4\downarrow$; ***[3 max]***
*Award **[2 max]** if no correct equations are given.*

*Accept other normal, basic or acid salts formed from $Fe^{3+}$/$Fe(OH)^{2+}$/$Ca^{2+}$ and $PO_4^{3-}$/$HPO_4^{2-}$/$H_2PO_4^-$.*
*Accept molecular equations instead of ionic.*
*Downward arrows after precipitates are not required.*

**E6.** winds/air currents distribute CFCs/ozone-depleting agents evenly in the atmosphere/ stratosphere;
at low temperatures (clouds of) ice/solid nitric acid trihydrate/ $HNO_3 \cdot 3H_2O(s)$ /solid particles/crystals form in stratosphere/upper atmosphere;
ice/solid surface catalyzes ozone decomposition / releases chlorine/$Cl_2$/hypochlorous acid/HOCl/chlorine oxide/(free) radicals; ***[3]***
*For M3, accept chemical reactions, for example:*
*$ClONO_2(g) + HCl(s) \rightarrow Cl_2(g) + HNO_3(s)$*
*$HOCl(g) + HCl(s) \rightarrow Cl_2(g) + H_2O(s)$ etc.*

**Option F — Food chemistry**

**F1.** (a) (i) ester; ***[1]***

(ii) carboxylic acid / carboxyl; ***[1]***
*Accept alkanoic acid.*
*Accept formulas.*

(b) (i) chocolate melts easily/solid state needs to be maintained in hot climates;
more crystalline fats / higher melting point/more saturated fats used; ***[2]***
*Accept converse arguments*.

(ii) in a hot climate more saturated / longer chain / more hydrogenated/*trans* fats used;
intermolecular forces stronger / more crystalline giving higher melting point; ***[2]***
*Accept converse arguments*.

**F2.** (a) *Type of rancidity:*
oxidative (rancidity) / photo-oxidation;

*Functional group:*
carbon-carbon double bond/C=C / alkene; ***[2]***

(b) aldehydes;
ketones;
amines; ***[2 max]***

(c) storage;
in fridge/freezer / low temperature reduces rate of reaction / absence of light / low moisture levels;

processing;
to limit lipase activity / keeping moisture levels low;

packaging;
excluding air/oxygen by using an inert gas / hermetic packaging to exclude oxygen / eliminating air from the head space / light-proof materials;

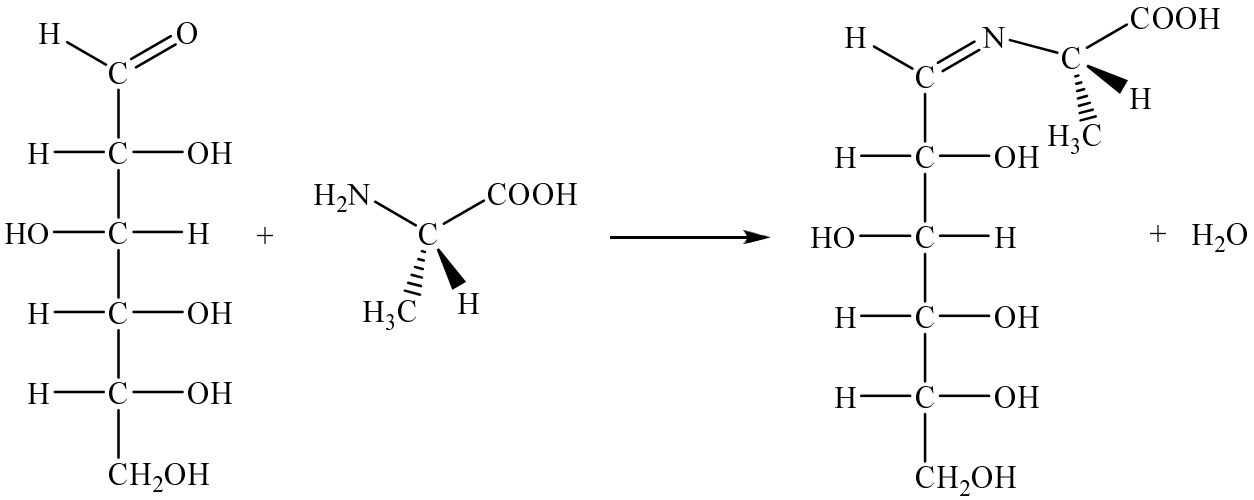
additives;
sodium hydrogensulfite or citric acid to prevent oxidation (and non-enzymic browning) / tocopherols to prevent free-radical oxidation anti-oxidants; ***[4 max]***

*Each method and correct example scores **[2 marks]**, up to **[4 max]**.*
*Two correct methods alone score **[2]**.*
*Two correct examples alone score **[2]**.*
*If examples don't match methods **[3 max]**.*

**F3.** (a) many polar/–OH/hydroxyl groups;
which can hydrogen bond to water; ***[2]***

(b) **A**;
in acid solution [$H^+$] high / **A** protonated; ***[2]***
*No ECF possible.*

**F4.**



double bond between $C_1$ of glucose and N of alanine;
water/ $H_2O$ ; ***[2]***
*Accept 2-D representations.*

**F5.** (a) CO for carboxyl, R for alkyl, N for nitrogen;
look at C with H behind;
D is CO–R–N clockwise / L if CO–R–N anti-clockwise; ***[3]***
*Accept suitable diagram for third mark.*

(b) natural products contain just one enantiomer/rotate plane polarized light;
artificial flavourings/colourings contain both enantiomers/racemate/do not rotate plane polarized light; ***[2]***

**Option G — Further organic chemistry**

*Only penalize missing or misplaced H atoms once in the questions.*

**G1.** (a) $CH_3CH_2CHO + HCN \rightarrow CH_3CH_2CH(OH)CN$; ***[1]***
*Allow more detailed formulas/reactions throughout the question.*

(b) (nucleophilic) addition/$A_N$; ***[1]***

(c) cyanohydrin(s)/hydroxynitrile(s); ***[1]***
*Accept correct IUPAC name of organic product in (a).*

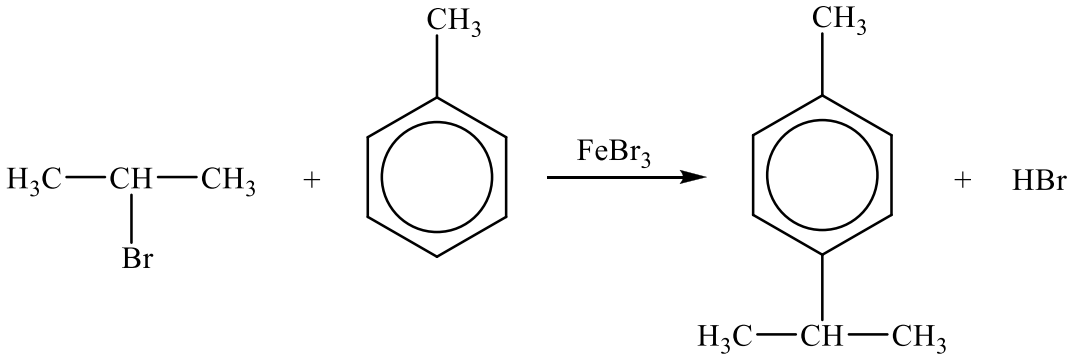
(d) $CH_3CH_2CH(OH)CH_2CH_3$; ***[1]***

(e) *Step 1*:
$CH_3CH_2CH_2Br + Mg \rightarrow CH_3CH_2CH_2MgBr$;
dry/anhydrous (solvents/reactants);

*Step 2*:
$CH_3CH_2CH_2MgBr + CO_2 \xrightarrow{H^+} CH_3CH_2CH_2COOH(+Mg^{2+} + Br^-)$;
$H^+$/acid (catalyst); ***[3 max]***
*Accept $H_2O$/water instead of $H^+$.*
*Award **[1 max]** for conditions.*

**G2.** $(CH_3)_2C(OH)CH_2CH_3$/$(CH_3)_2CHCH(OH)CH_3$;
$(CH_3)_2CBrCH_2CH_3$; ***[2]***
*Allow more detailed formulas.*

**G3.** (a)




correct formula of organic product;
inorganic product **and** catalyst; ***[2]***
*Accept 2-substituted product.*
*Accept metal Fe or any Lewis acid ($AlCl_3$/$AlBr_3$/$BF_3$/etc.) as catalyst.*

(b) (electrophilic) substitution/$S_E$; ***[1]***

(c) $CH_3$/methyl/alkyl group is an electron-donating/releasing substituent/has (positive) inductive effect / *OWTTE*; ***[1]***

**G4.** (a) increases acidity / *OWTTE*;
nitro groups are electron acceptors / nitro groups withdraw/pull electrons/have negative inductive effect;
(acceptors) increase O–H bond polarity / increase $\delta^+$ on H / decrease O–H bond strength / favour dissociation of O–H bond / stabilises phenolate ion / *OWTTE*; ***[3]***

(b) (3,5-dinitrophenol is) more acidic than phenol but less acidic than 2,4,6-trinitrophenol / *OWTTE*; ***[1]***

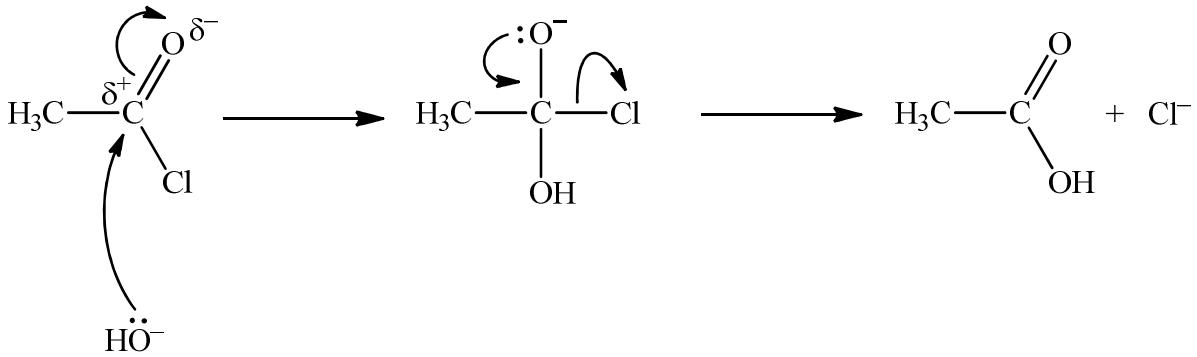
(c) 6.7; ***[1]***
*Accept any value in the range 0.43 –7.14.*

**G5.** (a) $(CH_3CO)_2O + C_6H_5NH_2 \rightarrow CH_3CONHC_6H_5 + CH_3COOH$; ***[1]***
*Allow more detailed formulas/reactions throughout the question.*

(b) addition-elimination/nucleophilic substitution/$S_N$; ***[1]***

(c) $CH_3COCl + (CH_3)_2CHOH \rightarrow CH_3COOCH(CH_3)_2 + HCl$; ***[1]***

(d)




curly arrow going from lone pair/negative charge on O in $HO^-$ to carbonyl C **and** curly arrow going from C=O bond to O;
*Partial charges not required.*
*Do not allow curly arrow originating on H in $HO^-$.*

representation of intermediate anion showing negative charge on O;
*Lone pair on O not required on representation of intermediate.*

curly arrow going from lone pair/negative charge on O to C–O to form C=O **and** curly arrow showing Cl leaving;
formation of final organic product **and** $Cl^-$; ***[4]***