M15/4/CHEMI/HP3/ENG/TZ1/XX/M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2015

Chemistry

Higher level

Paper 3

22 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.

14. Penalize missing hydrogens or incorrect bond linkages (*eg*, C–H_3C) once only.

Option A — Modern analytical chemistry

1. (a) $E = \frac{hc}{\lambda}$ / $E = \alpha \frac{1}{\lambda}$ / energy inversely proportional to wavelength / the higher the energy the shorter the wavelength / *OWTTE*; **[1]**
Do not accept $E = h\upsilon$/*hf*.

(b)

Information	Region of the electromagnetic spectrum
Bonds present in an organic compound	infrared/IR;
Concentration of Cr^{3+} ions in industrial waste waters	visible/vis; *Accept ultra-violet-visible/uv-VIS but not ultraviolet/UV.*

[2]

(c) (i) protons in water/carbohydrates/proteins/fats/lipids (can be detected by MRI); protons in different environments produce different signals/chemical shifts / protons in different environments absorb (radio waves) at different frequencies / *OWTTE*; **[2]**
Accept "hydrogens" for protons in M1 and M2.

(ii) (3D) image of organ (tissues) / can discriminate between tissues/ environments / can detect problems/abnormalities within body (without surgery); **[1]**
Accept suitable examples (eg, may identify cancer/(brain) tumours/multiple sclerosis/spinal infections/joint problems/hydrocephalus/osteomyletis/bone infections/(ischemic) stroke/blood vessel problems).

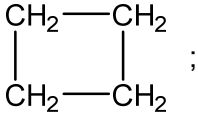
2. (a) (i) $C_4H_8^+$; **[1]**
Penalize missing charge only once in (i) and (ii).

(ii) $m/z = 27$: $C_2H_3^+/CH_2CH^+/CH_2{=}CH^+$ **and** $m/z = 29$: $C_2H_5^+/CH_3CH_2^+$; **[1]**
Penalize missing charge only once in (i) and (ii).

(b) (i) C=C/carbon–carbon double bond; **[1]**
Accept "alkenyl/alkene".

(ii) $CH_3CH_2CH{=}CH_2$; **[1]**
Accept either a full or a condensed structural formula.

(iii) produced by (Hs in) $=CH_2$ group;
adjacent C has 1 H atom;
$n+1$;
due to relative/(two) different orientations/alignment of spin of nuclei/protons/hydrogens (with applied/external magnetic field); **[3 max]**

(iv)  ; **[1]**
Accept full or condensed structural formula.

(c) (i) **C**: (mirror/beam splitter) splits beam into two beams;

D: provides a reference/control/baseline (for absorbance) / used to compare absorbance with the sample / allows measurement of absorbance without sample / determines background/solvent/air absorbance / reduces/eliminates systematic errors;

E: compares (the intensities of) sample and control/reference beams
OR
determines the absorbance (at particular frequencies); **[3]**
Accept "(photomultiplier) converts photons/IR radiation into current".
Accept "transmittance" for "absorbance" throughout.
*Award **[1 max]** if names given for **C:** mirror/beam splitter, **D:** control/ reference/solvent **and E**: detector/photomultiplier.*

(ii) (region where) bond bending occurs;
Accept "bending of molecule".

compound can be identified by distinctive/characteristic/complex pattern / (region of spectrum) used for comparison purposes with spectral libraries / *OWTTE*; **[2]**

3. (a) (i) alcohol 1 as retention time is smaller / alcohol 1 because ethanol (is/has) more volatile/smaller molecule/lower molar mass/lower molecular mass/weaker London forces/lower boiling point / *OWTTE*; **[1]**
Accept "dispersion/van der Waals/vdW/instantaneous induced dipole-induced dipole forces" for London forces.
Accept "less London forces" for "weaker London forces".
Accept "smaller number of electrons" for "lower molar mass".

(ii) blood sample I **and** relative area for ethanol to propan-1-ol is greater; **[1]**
Do not allow ECF from (a)(i).

(b) sample II since it has lower retention times (because molecules on average move faster/have greater kinetic energy); **[1]**
Justification must be given.

4. ***Any two** for **[2 max]** of:*
green light/radiation transmitted;
Accept "green light/radiation reflected".

red light/radiation absorbed / red is complementary colour / complementary colour absorbed;
"Light/radiation" only needs to be mentioned once in either M1 or M2.

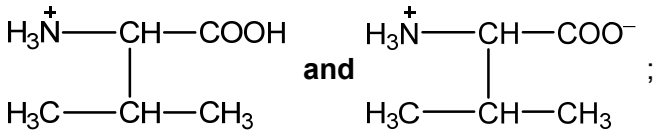
(as) electrons promoted into higher energy levels;
*Award **[1 max]** for "green transmitted **and** red absorbed".*

*Last marking point for **[1]**:*
(in visible region due to extensive) conjugation / alternate single and double (carbon–carbon) bonds / involves delocalization (of π electrons); **[3]**

Option B — Human biochemistry

5. (a) (i) arginine/Arg; **[1]**

(ii) ***Any two*** *from the following for* ***[1 max]****:*
alanine/Ala;
isoleucine/Ile;
leucine/Leu;
methionine/Met;
valine/Val;
phenylalanine/Phe;
tryptophan/Trp; **[1]**
Accept "proline/Pro".

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

Accept structural formula of zwitterion alone (as it's the dominant form).
Accept structural formula of cation alone (though lower in concentration than zwitterion based on equilibrium and pH calculations).
Accept full or condensed structural formula(s).

(b) gives strength to tendons/bones/ligament/skin/cornea/cartilage/blood vessels / connective tissue; **[1]**
Accept "elasticity" for "strength" but do not accept answers such as "protects bones" etc.
Accept just "structural".

6. (a) *Similarity in structure:*
both are (tri)esters / both made from glycerol/propane-1,2,3-triol/ $HOCH_2CH(OH)CH_2OH$;

Difference in structure:
phospholipids have phosphate group/phosphorus **and** fats are triglycerides/made from three fatty/carboxylic acids / one fatty/carboxylic acid (in fat) replaced by phosphate in phospholipid;

Difference in polarity:
phospholipids are more polar / phospholipids have hydrophilic (heads/section/part/end) / fats are less polar/non-polar / fats are hydrophobic; **[3]**

(b) *Composition:*
HDL has more protein **and** less cholesterol/fat/lipid (and vice-versa);
*Accept "HDL has more protein **and** LDL has more cholesterol (and vice-versa)".*
Accept "HDL has higher phospholipid content compared to LDL (and vice-versa)".
Accept "HDL particles are smaller than LDL particles (and vice-versa)" but do not penalize if "molecules" are used instead of "particles".

One effect on health:
cardiovascular problems/increased risk of heart disease/obesity/atherosclerosis/blocked arteries from high ratio of LDL to HDL; **[2]**
Accept "from (high) LDL" instead of "from high ratio of LDL to HDL".
Accept "can result in a heart attack/stroke from high ratio of LDL to HDL".
Accept "large amounts of HDL in blood correlate with good health / OWTTE".

Reference must be made to LDL or HDL.

(c) (i) forms complex ions/complexes;
Fe^{2+} **and** Fe^{3+} / variable oxidation states/numbers (in redox reactions); **[2]**
Accept "catalytic" but do not accept just "high charge density".

(ii)

	Complex	Oxidation state(s)
Role of iron ions in oxygen transport	hemoglobin/heme B *Accept "iron-porphyrin" but not just "porphyrin".*	+2;
Role of copper ions in electron transport	cytochrome (c)	+1 **and** +2;

[2]

*Award **[1 max]** for two correct complexes **OR** for two correct oxidation states.*
Accept Roman numeral notation (II for +2 and I for +1) but not incorrect notation such as charged species (2+, 1+) or oxidation states without the + sign (eg 2 and 1).
Penalize incorrect notation for oxidations states once only.

7. (a) structure/function similar to testosterone;
causes increased rate of protein synthesis/tissue/muscle building/increase in muscle mass / *OWTTE*; **[2]**
Accept "anabolic" for M2.

(b) *Similarity in structure:*
(both have) carbon–carbon double bond/C=C (group)
Accept "alkenyl/alkene" for C=C.

OR

(both have) carbonyl/C=O (group);
Accept "ketone/alkanone" for carbonyl.

Difference in structure:
(**G** has) alkynyl/C≡C
Accept "alkyne" for C≡C.

OR

(**G** has) hydroxyl/OH (group)
Accept "alcohol/hydroxy" but not hydroxide for OH.

OR

(**G** has) one less carbonyl/C=O (group); **[2]**
Accept "ketone/alkanone" for carbonyl.

Answers must be in terms of functional groups only for this question.

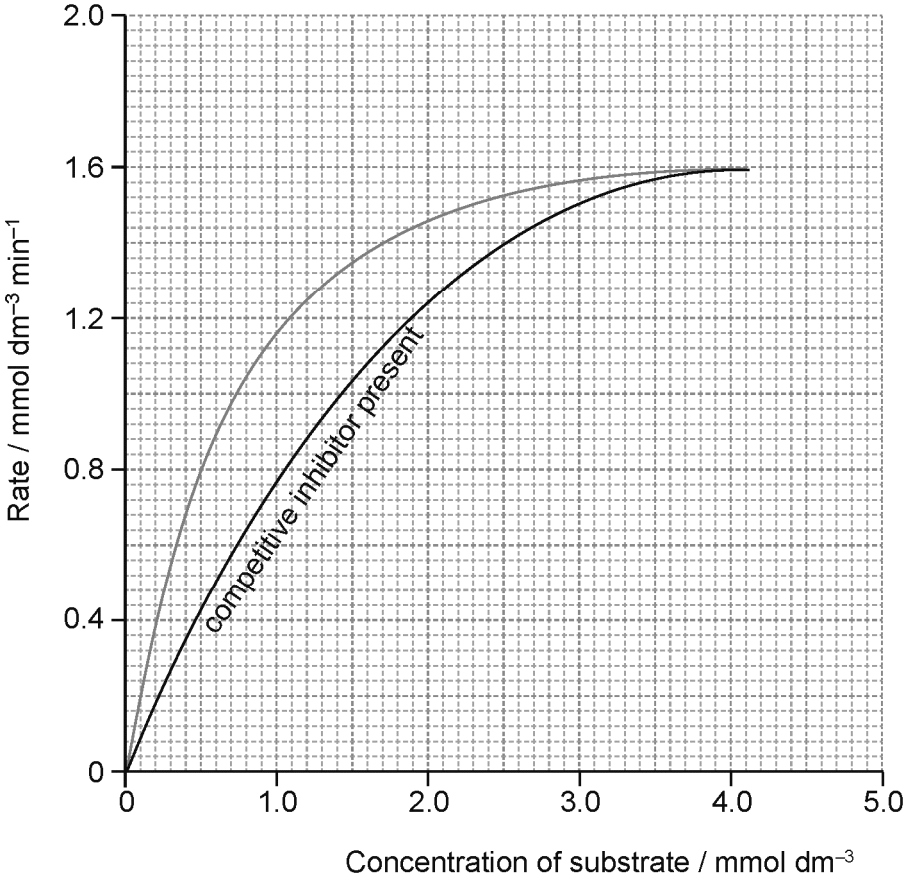
8. (a) at low concentration, as [S] increases rate increases/is first order
OR
at low concentration more enzyme molecules can combine with substrate molecules as [S] increases;

at high concentration rate reaches a maximum/is zero order/is constant
OR
at high concentration (all) active sites used up/occupied; **[2]**
Accept "at high concentration enzyme is saturated with substrate/saturation is reached".

There must be a reference to low concentration to score M1 and to high concentration to score M2.
*Award **[1 max]** for stating "as [S] increases rate increases" if no other mark scored.*
Accept "(enzyme) activity" for "rate" throughout.

(b) inhibitors have similar structure to the substrate;
they bind to/occupy/compete for the active sites;
fewer substrate molecules able to react / inhibitors blocks active site; **[2 max]**

(c)



On the graph look for:
same maximum/V_{max};
the curve is less steep (than without inhibition); **[2]**
*Award **[1 max]** if curve does not go through the origin.*

(d) *V_{max}:*
decreases;
K_m:
no change; **[2]**

Option C — Chemistry in industry and technology

9. (a) (i) $+\frac{8}{3}$ / $+2\frac{2}{3}$;

Accept +2.7 but not +3.

+2 **and** +3 / contains two (or more) iron ions with different oxidation states / contains Fe^{2+} **and** Fe^{3+}; **[2]**

Accept II and III oxidation number notation for oxidation states but not 2+ and 3+ unless ions are referred to explicitly.
*Accept "contains different iron compounds/FeO **and** Fe_2O_3".*

(ii) $Fe_3O_4(s) + 4CO(g) \rightarrow 3Fe(l) + 4CO_2(g)$; **[1]**

*Accept "$Fe_3O_4(s) + CO(g) \rightarrow 3FeO(s) + CO_2(g)$ **and** $FeO(s) + CO(g) \rightarrow Fe(l) + CO_2(g)$".*
Ignore state symbols.

(b) (heat to a) high temperature/approximately 1000 °C **and** cool (slowly);
Accept any temperature greater than or equal to 500 °C but do not award mark if there is any reference to "cooling rapidly".

(makes steel) more malleable / more ductile / less brittle; **[2]**
Accept "(makes steel) softer".

10. (a)

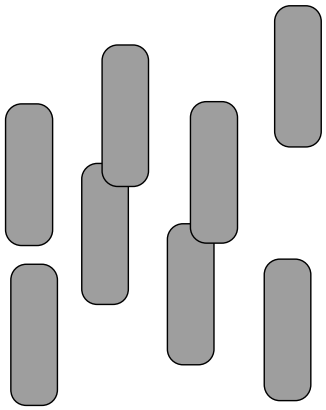


diagram should have molecules with a parallel alignment in any direction (not just upwards);
diagram should have molecules in an irregular arrangement in space; **[2]**
Ignore relative separation between molecules.
*Award **[1 max]** if number of molecules < 7.*
*Award **[1 max]** if stated "molecules align parallel to each other but with an irregular arrangement in space / OWTTE" but with no diagram drawn.*
Allow the representation of molecules by lines.

(b) (i) polar/dipole moment due to the presence of C≡N (bond) / difference in electronegativity between C and N; **[1]**

(ii) molecules become more ordered / molecules unable to change orientation (as they approach fixed arrangement of solid state) / molecules move slower / viscosity (of medium) increases (so LCD response time increases); **[1]**

(c) (nematic) LC's placed between (two glass) plates/sheets with (two) polarizing filters at 90° to each other / each pixel contains LC (film/molecules) sandwiched between (two glass) plates/sheets;
plates/sheets have (fine) scratches/grooves **and** LC molecules (in contact with glass) align with these;
LC molecules adjacent to top layer are orientated at 90° to those adjacent to bottom layer / *OWTTE*;
LC molecules align in twisted (nematic) arrangement due to intermolecular forces;
Accept "intermolecular bonds" for "intermolecular forces".

LC interacts with (plane-)polarized light which is rotated 90°;
when molecules are aligned (with the scratches) light will pass through (and pixel appears bright);
when a potential difference/voltage is applied molecules align with electric field (losing their twisted structure);
they no longer allow (polarized) light to pass (and pixel appears dark); **[4 max]**

A suitably labelled diagram may be used to explain some marking points.

11. (a) pentane/volatile hydrocarbon added (during polymerization process);
heating causes pentane/volatile hydrocarbon to evaporate/vaporize/produce bubbles of gas (expanding the polystyrene); **[2]**
Accept other suitable identified blowing agents such as carbon dioxide.

(b) *Advantages:*
***Any two** for **[2 max]**:*
low/reduced density;
Accept "small mass".
Do not accept "light".

can be shaped (around object);
good shock absorber;
insulator;

Disadvantage:
*Award **[1]** for disadvantage:*

disposal takes up a lot of space (in landfill); **[3]**
Accept "non-biodegradable/polluting/hazardous to wildlife".

12. (a) only allows cations/Na^+ to pass / prevents anions/Cl^- **and** OH^- to pass;
prevents Cl_2 **and** OH^-/NaOH reacting; **[2]**
*Award **[1 max]** for "does not allow gaseous **and** liquid species to pass".*
Do not accept "completes the circuit".

(b) ***K:*** chlorine/Cl_2 **and** ***M:*** sodium hydroxide/NaOH; **[1]**

(c) *Negative electrode (cathode):*
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$;
Accept $2H^+(aq) + 2e^- \rightarrow H_2(g)$.

Positive electrode (anode):
$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$; **[2]**

*Award **[1 max]** for correct equations at incorrect electrodes.*
Ignore state symbols.
Accept e for e^-.
Accept corresponding half-equations involving one e^-.

(d) membrane cell has a polymer/PTFE/polytetrafluorethene membrane **and**
diaphragm cell uses (diaphragm made of) asbestos;
Accept Teflon for PTFE.

membrane cell allows only Na^+ ions to pass through **and** diaphragm cell allows both Na^+ and Cl^- ions to pass through;
NaOH solution is purer in membrane cell / NaOH contaminated with NaCl in diaphragm cell; **[2 max]**

Option D — Medicines and drugs

13. (a) (i) lone pair/non-bonding/electron pair on nitrogen (atom)/amino (group);
Accept "amine" for "amino".

reacts with H^+ / donates lone/non-bonding/electron pair to H^+ / acts as Lewis base;
Accept "proton/H^+ acceptor".
Do no accept "produces OH^-" for M2.
*Award **[1 max]** for "contains amino/amine".* **[2]**

(ii) dissolves in aqueous medium in body / *OWTTE*; **[1]**
Accept "(passes through) lungs/cell membrane".
Do not accept "inhalation".

(iii) transdermal / patches / absorbed through skin;
(per)oral / gum / polacrilex / tablets/pills / lozenges / pastille;
(intra)nasal (spray); **[2 max]**
Accept "injection" (if NicVAX mentioned only).
Accept "inhalers".
Do not accept "electronic/e-cigarettes".

(b) (i) tetrahydrocannabinol/THC; **[1]**

(ii) relieves nausea/vomiting/pain in cancer/AIDS/HIV patients / relieves coughing/dilates respiratory passages in patients with asthma/respiratory problems / relieves uncontrollable limp spasms/relaxes muscles in patients with Parkinson's disease/multiple scelerosis/epilepsy/Huntington's disease /increases appetite for patients with AIDS/HIV/cancer; **[1]**
Accept answers such as "mentally relaxes terminally ill patients" / OWTTE.
Accept "(may) lower eye pressure in the treatment of glaucoma".

A specific effect on a named disease must be stated.

14. (a) nucleic acid / DNA/deoxyribonucleic acid / RNA/ribonucleic acid;
protein; **[2]**
Accept "(surrounded by coat of protein units called) caposemers / (surrounded by protective protein shell called a) capsid".
*Award **[2]** for "nucleoprotein".*

(b) alter cell's genetic material;
(changes cell membrane so that it) inhibits virus entry/binding to cell;
prevents virus from leaving cell (after reproduction);
becomes part of DNA of virus / alters virus / blocks enzyme (polymerase) which builds DNA;
prevents virus from using cell to multiply/reproduce/replicate; **[2 max]**
Do not accept "blocks enzyme activity within host cell / OWTTE".

(c) HIV mutates (rapidly) / *OWTTE*;
Do not accept "AIDS mutates" without mention of the virus.

HIV destroys (T-)helper cells/white blood cells/lymphocytes / HIV attacks immune system; **[2]**
Penalize the use of "AIDS" for "HIV" once only.
Do not accept general answers based on "cost of drugs" or "cost of development".

15. (a) (i) $NaOH/Na_2CO_3/NaHCO_3$; **[1]**
Do not accept alkali, base or OH^-.
Accept either a correct chemical formula or name.

(ii) increases aqueous/water solubility;
facilitates distribution (in the body) by the bloodstream / *OWTTE*; **[2]**

(b) (i) *Similarities:*
*Award **[1 max]** for **any two**:*
benzene ring/aromatic ring/$–C_6H_2$;
Accept "phenyl" or "arene" but not C_6H_5- or benzene/C_6H_6.

(tertiary) amino/–NRR'/NRR'R";
Accept "(tertiary) amine".

carbon–carbon double bond/C=C;
Accept "alkene" or "alkenyl".

ether/C–O–C;

Accept "both have the same ring structure / OWTTE".

Difference:
ester/CH_3COO in diamorphine/heroin **and** hydroxyl/OH in morphine; **[2]**
Accept "ethanoate" for ester.
Accept "alcohol" or "hydroxy" for hydroxyl but not hydroxide.

(ii) ethanoic acid/CH_3COOH / ethanoyl chloride/CH_3COCl / ethanoic anhydride/$(CH_3CO)_2O$; **[1]**
Accept "acetic acid", "acetyl chloride", "acetic anhydride" or "ethanoyl-ethanoate".
Do not accept "carboxylic acid".

(c) diamorphine is less polar/non-polar / morphine is more polar / polar groups in morphine are replaced with less polar/non-polar groups in diamorphine;
(less polar molecules) cross blood-brain barrier faster/more easily / (diamorphine) more soluble in non-polar environment of CNS/central nervous system / (diamorphine) more soluble in lipids; **[2]**

16. (a) many/variety of (poly)peptides/polymers produced (together);

*Award **[1 max]** for any one of:*
separation/purification is (relatively) easy / products can be isolated by washing **and** filtration;
process can be automated/performed by robots; **[2]**

(b) molecular/3D modelling of receptors/pharmacophores/binding sites / molecular/3D modelling used to study drug-receptor interactions;
virtual synthesis of drugs / *OWTTE*;
evaluation of (biological/pharmacological) effects of new drugs / *OWTTE*; **[2 max]**

Option E — Environmental chemistry

17. (a) **Q**;

waste needs oxygen to decompose/decay/be broken down (and so there is a decrease in oxygen concentration after the factory) / waste increases BOD/biochemical/biological oxygen demand; **[2]**

(b) (i) $3Ca^{2+}(aq) + 2PO_4^{3-}(aq) \rightleftharpoons Ca_3(PO_4)_2(s)$; **[1]**

Ignore state symbols.
Accept single arrow sign.

(ii) $(K_{sp} =) [Ca^{2+}]^3 [PO_4^{3-}]^2$; **[1]**

Ignore state symbols.
Do not award mark if incorrect brackets are used or are missing.

(iii) Let x be solubility so $2.07 \times 10^{-33} = (3x)^3(2x)^2$;

Remember to apply ECF from (ii).

$x^5 = \frac{2.07 \times 10^{-33}}{(27 \times 4)} / 1.92 \times 10^{-35}$ / $x = 1.14 \times 10^{-7}$;

$\left([Ca^{2+}] = 3x =\right)$ 3.42×10^{-7} (mol dm^{-3}); **[3]**

*Award **[3]** for final correct answer.*

(c) heat / thermal pollution / increase in temperature (of water); **[1]**

18. (a) (i) $\left(\lambda = \frac{3.0 \times 10^8}{3.5 \times 10^{13}} =\right) 8.6 \times 10^{-6}$ (m); **[1]**

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

(b) N_2O; **[1]**

(c) CO_2 has a (much) greater relative contribution (to increased global warming compared to N_2O) since it is more abundant;

CO_2 is less effective at absorbing IR/radiation/heat / greenhouse factor/greenhouse warming potential/GWP of CO_2 is (considerably) less than N_2O; **[2]**
Accept "CO_2 absorbs less IR/radiation/heat (or vice versa for N_2O)".
Accept converse arguments.

19. (a) harvesting/removal (of crops) / irrigation (removes soluble nutrients) / acidification through addition of fertilizer;
Do not accept "salinization".

(nutrients replaced by) compost/(artificial) fertilizer / crop rotation; **[2]**
Do not accept "humus".

(b) (i) has many (polar) hydroxyl/OH/carboxyl/COOH (groups);
Accept "alcohol/hydroxy" for hydroxyl and "carboxylic acid" for carboxyl but not hydroxide for hydroxyl.

can form (many) hydrogen bonds (with water molecules in the soil); **[2]**

(ii) increases ability of soil to buffer changes (in pH);
Accept "affects pH of soil".

binds to organic and inorganic compounds in soil / nutrients not washed away easily;
forms complexes with cations / can absorb heavy metal cations (preventing them from being absorbed by plants);
reduces negative environmental effects of pesticides/heavy metals/ pollutants / can bind contaminants / *OWTTE*;
has cation exchange capacity/CEC capacity / *OWTTE*; **[2 max]**

(iii) reduces soil biodiversity / disrupts balance of microorganisms in soil;
acidification of soil;
disrupts food webs/cycles;
stimulates growth of harmful bacteria; **[2 max]**
Accept "unbalanced fertilizer use leads to nutrient deficiencies".

20. (a) O_3 needs less energy/has weaker bonding/has lower bond enthalpy;
Accept converse argument for O_2.

O_3 has bond order 1.5/intermediate between double and single **and** O_2 has bond order 2/double bond; **[2]**

(b) $NO\bullet(g) + O_3(g) \rightarrow NO_2\bullet(g) + O_2(g)$;
$NO_2\bullet(g) + O\bullet(g) \rightarrow NO\bullet(g) + O_2(g)$; **[2]**
Accept "$NO_2\bullet(g) + O_3(g) \rightarrow NO\bullet(g) + 2O_2(g)$" for M2.
Accept NO, NO_2 and O for radicals without • if used consistently.
Accept equations with NO and NO_2 written without • but with O• written.
Ignore state symbols.

Option F — Food chemistry

21. (a) *Food:*
substance (intended) for consumption;
Nutrient:
obtained from food **and** used by body for metabolism/to provide energy/regulate growth/repair body tissues; **[2]**

(b) (i) *Similarity:*
both are (tri)esters / both made from glycerol/propane-1,2,3-triol/$HOCH_2CH(OH)CH_2OH$ / both are triglycerides;

Difference:
unsaturated fats have C=C/carbon–carbon double bond / saturated fats have no C=C/carbon–carbon double bonds; **[2]**

(ii) *trans* fat;
greater RMM/relative molecular mass / larger number of electrons / longer carbon/hydrophobic chains / *OWTTE*; **[1 max]**

(c)

Nutrient	Purpose
proteins **and**	provide amino acids for protein/enzyme production / growth / repair / hormone synthesis;
carbohydrates **and**	energy (source);
vitamins **and**	to protect health / for (normal) growth / for metabolism / co-factor / prosthetic group / for healthy vision/skin / for (normal) cell function / prevents specific diseases;
minerals **and**	to protect health / (regulate) growth / for metabolism / for nerve functioning / for fluid balance / oxygen transport / for muscle contraction / for healthy bones/teeth/ immune system / prevent blood clotting / regulates blood pressure / for acid-base balance / for (normal) cell function;

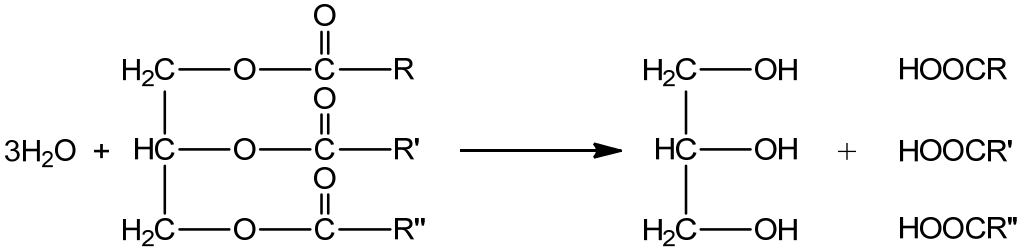
[2 max]

*Award **[1]** for two correct nutrients without correct purpose*.

22. (a) *Shelf life:*
time after which food no longer maintains the expected quality/flavour/smell/texture/appearance (desired by consumer);

"Best-before" date:
usually (well) within the expected shelf life period (to cover retailers/manufacturers from litigation) */* best-before date is less than shelf life */ OWTTE*; **[2]**

(b) *Reaction 1:* hydrolytic (rancidity)/hydrolysis **and**



OR
hydrolytic (rancidity) **and** hydrolysis of ester links/breaking down of lipid/fat to glycerol/propane-1,2,3-triol **and** fatty/carboxylic acids;

Reaction 2: oxidative (rancidity)/oxidation **and**
addition of O_2 across C=C/carbon-carbon double bonds / oxidation of C=C/carbon–carbon double bonds; **[2]**
Do not penalize omission of "carbon–carbon" if already penalized in F.21(b)(i).

*Award **[1 max]** for "hydrolytic (rancidity)/hydrolysis" and "oxidative (rancidity)/oxidation" only.*

23. (a) *When shaken together:*
(cloudy) emulsion (of oil in vinegar) / form an apparent mixture / form a cloudy (turbid) mixture / *OWTTE*;
Accept "oil droplets in vinegar".

After standing:
separates into two layers; **[2]**
Ignore which layer is on top.

(b) charged nitrogen/ammonium/oxygen/phosphate/ionic/polar/hydrophilic head/end/part interacts with/dissolves in aqueous layer/vinegar;
hydrocarbon/non-polar/hydrophobic end/tail/part interacts with/dissolves in oil; **[2]**
*Award **[1 max]** for stating "has both polar/ionic/hydrophilic **and** non-polar/hydrophobic/hydrocarbon tail/ends/parts".*

24. (a) red light/radiation transmitted;
Accept "red light/radiation reflected".

green light/radiation absorbed / green is complementary colour / complementary colour absorbed;
"Light/radiation" only needs to be mentioned once in either M1 or M2.
*Award **[1 max]** for "red transmitted **and** green absorbed".*

(as) electrons promoted into higher energy levels;
(in visible region due to extensive) conjugation / alternate single and double (carbon–carbon) bonds / involves delocalization (of π electrons); **[3 max]**

(b) anthocyanins are (water) soluble but carotenes are insoluble;

anthocyanins have hydroxyl/OH/polar groups (so are water soluble) / anthocyanins can form hydrogen bonds with water / carotenes have no hydroxyl/OH/polar groups/are non-polar (so not water soluble) / carotenes do not form hydrogen bonds with water / carotenes have long hydrophobic parts / *OWTTE*; **[2]**
Accept "alcohol or hydroxy" for hydroxyl but not hydroxide.

(c) (rotate structure so) H/lowest priority atom at the rear;
order remaining groups in priority of substitution of carbon/atomic number of nearest substituent;
Do not award M2 if reference is made to molecular/molar mass.

(order of priority decreases) anti-clockwise (so S); **[3]**

(d) D/L used for carbohydrates **and** amino acids / D/L uses glyceraldehyde as a reference;
*Accept Fischer-Rosanoff/Rosanoff (convention) for carbohydrates **and** amino acids*.
Do not accept just "CORN rule used for amino acids".

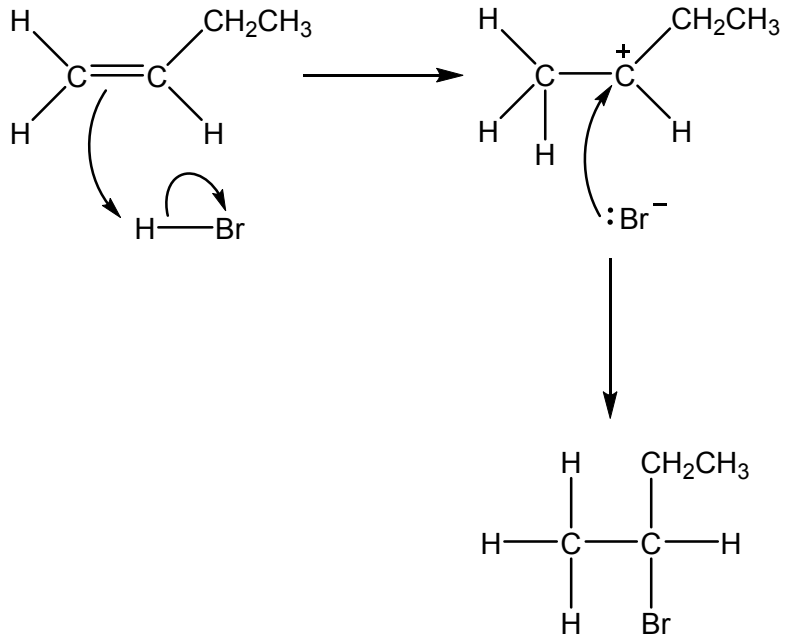
no relationship */ OWTTE;* **[2]**

Option G — Further organic chemistry

25. (a) *Reagent:*
HBr/hydrogen bromide;

Type of reaction:
electrophilic addition; **[2]**

(b) (i)



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

(ii) (intermediate) $CH_3CH_2^+CHCH_3$ is more stable than $CH_3CH_2CH_2^+CH_2$;
Accept "secondary carbocation more stable than primary carbocation".

electron releasing/inductive effect of $-CH_2CH_3$ plus $-CH_3 > -CH_2CH_2CH_3$ /
two electron releasing R groups on secondary carbocation compared to one on the primary carbocation; **[2]**
Comparison required for M2 but accept "electron releasing/inductive effect of two R groups spreads positive charge more (so more stable)".

26. (a) $C_6H_5OH \rightleftharpoons C_6H_5O^- + H^+$ / $C_2H_5OH \rightleftharpoons C_2H_5O^- + H^+$;
Accept corresponding equations with water.
Accept a single arrow.

EITHER

positive inductive effect (of alkyl group) in ethanol;
strengthens OH bond / makes release of H^+ difficult;
Accept converse argument for phenol.

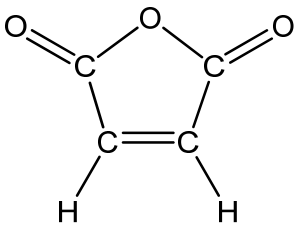
OR

lone/non-bonding pair on oxygen/negative charge on phenoxide anion/ $C_6H_5O^-$ can delocalize/spread round benzene ring;
so charge density decreases / phenoxide ion is stabilized; **[3]**
Accept converse argument for ethanol.

M2 can be gained from suitably labelled diagram.

(b) nitro group electron withdrawing / conjugation extends to nitro group;
Accept "nitro group is ring deactivating/decreases electron density around ring".

electrons pulled away from ring/O–H bond/O^- in anion;
so H^+ leaves (more) easily / more protons lost meaning 4-nitrophenol more acidic / O–H bond is weaker (in 4-nitrophenol) so 4-nitrophenol more acidic / more stable anion so 4-nitrophenol more acidic; **[3]**
*Award **[1 max]** for stating that "4-nitrophenol is more acidic" if no other marks scored.*

27. (a) 

$+ H_2O \rightarrow HOOCCHCHCOOH$; **[1]**
Accept "$C_4H_2O_3 + H_2O \rightarrow C_4H_4O_4$".

(b) (di)carboxyl **and** carbon–carbon double bond; **[1]**
*Accept "(di)carboxylic acid **and** alkene/alkenyl".*
Do not allow ECF from (a).

(c) addition-elimination / nucleophilic substitution/S_N; **[1]**
Do not accept just "substitution".

28. (a) *Reagent:*
Mg/magnesium;

Condition:
anhydrous/dry / ether/ethoxyethane/non-polar solvent; **[2]**
Accept "heat".

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

29. (a) (i) *Type of reaction:*
electrophilic substitution/S_E;

Reagents:
concentrated nitric acid/HNO_3 **and** concentrated sulfuric acid/H_2SO_4; **[2]**
Award mark if concentrated mentioned once only.

(ii) $HNO_3 + H_2SO_4 \rightleftharpoons NO_2^+ + HSO_4^- + H_2O$
Accept single arrow.

OR

$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ **and** $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$; **[1]**

(b) *Nitration, then alkylation:*
formation of 3-substituted/meta-substituted product;
nitro group is electron withdrawing (from the benzene ring);

Alkylation, then nitration:
formation of 2- and/or 4- substituted/ortho-para-substituted product;
alkyl group activates the (benzene) ring / alkyl group has inductive effect (increasing electron density of ring); **[3 max]**
Accept structural formulas for products in M1 and M3.