M15/4/CHEMI/HP3/ENG/TZ2/XX/M

Markscheme

May 2015

Chemistry

Higher level

Paper 3

20 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 <u>underlined</u> 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.

	Investigation	*Technique*
A	*Determining the sodium ion concentration in bottled water*	atomic absorption/AA (spectroscopy);
B	*Determining whether an organic molecule contains a C=O bond*	infrared/IR (spectroscopy); *Accept ^{13}C NMR.*
C	*Determining the molar mass of an organic molecule*	mass spectrometry/spectroscopy / MS;
D	*Determining the effect of changing the ligand from H_2O to NH_3 on the difference in energy of the d orbitals of a transition metal*	ultraviolet/visible/UV-Vis (spectroscopy);
E	*Detecting the presence of dioxin as an impurity in a herbicide*	gas-liquid chromatography/glc / high-performance/high pressure liquid chromatography/hplc; *Do **not** accept just "chromatography".*

[5]

2. (a) $CH_3CH_2COCH_2CH_3$;
Accept full or condensed structural formula.

*Any two for **[2 max]** from:*
two H (atom)/proton environments;
3:2/2:3 ratio of atoms in these environments;
one environment an alkyl group / one environment next to a carbonyl; **[3]**
Accept $–CH_3$ (0.9–1.0 ppm) / $–CO–CH_2–$ (2.2–2.7 ppm)

(b) next to a carbon atom bonded to two H atoms/protons / *OWTTE*; **[1]**

(c) changes in absorption frequency (very) small / magnetic field can vary (slightly);
Accept "providing a point from which to measure the shift" / OWTTE.

only single signal / well removed from other signals / very strong absorption / chemically inert / non-toxic / easily removed from sample; **[2]**

3. (a) peaks at $(m/z =)62$ **and** 64 / two molecular ion peaks;
height ratio of molecular ion peaks is $3:1$;
peak at $(m/z =)27$ (due to loss of Cl); **[2 max]**
Accept peaks at 63/65 (^{13}C)/peak(s) resulting from ^{13}C / peaks at 61/63 (loss of H)/peak(s) resulting from loss of H / peaks at 48/50 (loss of CH_2)/peak(s) resulting from loss of CH_2/ 35/37 Cl^+ as an alternative to final marking point.

(b) absorption at 600 – 800 (cm^{-1} C–Cl);
absorption at 1610 – 1680 (cm^{-1} >C=C<);
absorption at 2850 – 3100 (cm^{-1} C–H); **[2 max]**

(c) bends/stretches/vibrates;
<u>change in</u> bond polarity/dipole; **[2]**

4. (a) sample is injected (into the column); **[1]**
Accept "added" instead of "injected".

(b) *t* : the identity of the substance;
Accept "the relative attraction of the molecule for the stationary and mobile phases" / *OWTTE.*

A: the concentration/amount of the substance; **[2]**

(c) more strongly adsorbed onto/attracted by the Al_2O_3/packing/stationary phase;
Accept "more strongly bonded onto…".
Do ***not*** *accept "a**b**sorbed".*

less soluble in the hexane/solvent/mobile phase; **[2]**
For both, accept opposite statements relating to the behaviour of a less polar substance.

5. (a) **A and** more extensive delocalization/conjugation/alternate single and double bonding; **[1]**
Reference must be made to extensive/greater degree – conjugation alone is ***not*** *enough.*

(b) blue/blue-green coloured;
absorbs red/orange/complementary colour of blue; **[2]**
Award ***[1 max]*** *for violet as absorbs yellow light.*

Option B — Human biochemistry

6. (a) (i) hydrolyse/break peptide bonds;
heat/boil with (concentrated) hydrochloric acid/HCl; **[2]**
Accept NaOH / enzymes.

(ii) 0.50; **[1]**
Accept answers in the range 0.49–0.51.
Accept d/t.

(b) (i) E–S complex forms / substrate attracted to active site of enzyme / substrate held in active site by intermolecular forces;
induced fit / lock and key / *OWTTE*;
product released (from active site) after reaction; **[2 max]**
*Award **[1 max]** for answers giving at least **two** characteristics of catalysts in general.*

(ii) enzyme specific **and** Ni non-specific/can catalyse many reactions;
enzyme works in narrow temperature range/ $37–42\,^{\circ}\mathrm{C}$ **and** Ni is effective at high temperatures/wide temperature range;
enzyme is homogeneous **and** Ni is heterogeneous;
enzyme produces intermediate with reactant **and** Ni adsorbs reactant molecules onto its surface / Ni weakens bonds in reactants;
enzyme denatured by high pH and Ni is not; **[2 max]**
*Award **[1 max]** for any **two** correct catalytic action characteristics for either the enzyme or nickel.*
*Do **not** accept a difference based on reaction rate, such as "enzymes increase reaction rates anywhere from 10^3 up to 10^{20}, whereas inorganic catalysts increase rates much less".*

7. (a) both have straight chain/C_1 to C_4 linkage;
amylose (is a polymer of) α-glucose **and** cellulose (is a polymer of) β-glucose / amylose contains α-linkages (between monomers) **and** cellulose contains β-linkages (between monomers); **[2]**

(b) aerobic produces carbon dioxide and water **and** anaerobic produces lactate/ lactic acid;
*Do **not** award if CO_2 also given as a product of anaerobic respiration, unless related to ethanol/fermentation.*

[2]

more energy is released via aerobic respiration;
Accept aerobic produces more ATP/adenosine 5'-triphosphate (for energy).
Accept opposite statements for anaerobic respiration.

8. (a) assists brain function;
enables normal growth/development;
involved in synthesis of prostaglandins;
reduces (risk of) heart disease/blockage of arteries;
lowers blood pressure;
reduces LDL cholesterol;
increases HDL cholesterol; **[2 max]**
*Do **not** accept bad/good instead of LDL/HDL .*

(b) $n_{\text{iodine}} = 3n_{\text{linolenic acid}}$;
iodine number $\left(= \frac{3 \times 100 \times 253.8}{278.48}\right) = 273\,(\text{g})$; **[2]**
*Award **[2]** for final correct answer.*
*If alternative definition, in terms of moles/C=C bonds is given, award **[1 max]** for iodine number = 3.*

9. ensuring fresh/vitamin-rich/mineral-rich foods present in diet/food (rations);
genetically modifying food (to increase nutrient levels);
food additives / adding nutrients to commonly consumed food; **[2 max]**
Accept specific examples.

10. (a) *Present in both:*
alkenyl **and** hydroxyl;
*Accept alkene **and** alcohol/hydroxy but not hydroxide.*

Present only in aldosterone:
carbonyl **and** aldehyde; **[2]**
Accept ketone (for carbonyl).
Accept <u>primary</u> hydroxyl/alcohol.
*Award **[1 max]** if correct formulas, rather than names, given for **both**.*

(b) adrenal cortex/gland; **[1]**

(c) *progesterone:*
sexual development in females / menstrual/reproductive cycles in women;

OR

testosterone:
sexual development in males; **[1]**

Accept any specific function of progesterone/testosterone.

11. (a) (backbone of) sugar-phosphate;
nitrogenous bases attached to sugar;
four (different) nitrogenous bases / C, T, A and G;
sugar is a pentose; **[2 max]**

(b) DNA hydrolyzed/broken down at specific base sequences / restriction enzymes hydrolyze/break down DNA into small (polynucleotide) fragments;
polymerase chain reaction/PCR produces many copies of DNA portions;
gel/column electrophoresis separates fragments/DNA sequences by size;
UV light/X-ray film/^{32}P radioactive labelling used to see bands of DNA; **[2 max]**

Option C — Chemistry in industry and technology

12. (a) $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$ / $Fe_2O_3(s) + 3H_2(g) \rightarrow 2Fe(l) + 3H_2O(g)$ / $2Fe_2O_3(s) + 3C(s) \rightarrow 4Fe(l) + 3CO_2(g)$ / $Fe_2O_3(s) + 3C(s) \rightarrow 2Fe(l) + 3CO(g)$; **[1]**

Ignore state symbols.

(b) slag is immiscible with liquid iron **and** is tapped off;

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$;

$CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$ / $CaO(s) + Al_2O_3(s) \rightarrow CaAl_2O_4(l)$/$Ca(AlO_2)_2(l)$; **[2 max]**

*Award **[1 max]** for equations that combine those above, such as*
$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$.
Ignore state symbols.

(c) (re)heat (to between $200\,^\circ C$ and $600\,^\circ C$) **and** cool <u>slowly</u>;
becomes more springy/less brittle; **[2]**
Accept more malleable.

13. (a) mercury is toxic / formation of toxic organo-mercury compounds / mercury can enter food chain;
Accept specific health problems associated with mercury.

asbestos in diaphragm cell is a health hazard / causes lung diseases/ respiratory problems;
Accept specific health problems associated with asbestos.

membrane cell cheaper to build/construct;
membrane cell more efficient / cheaper to operate / uses less electricity;
membrane cell gives purer product; **[2 max]**
For last 3 marking points accept opposite statements referring to mercury/diaphragm cells.

(b) *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]** if reactions are at the wrong electrode.*
Ignore state symbols and/or reversible arrows.
Accept corresponding half-equations involving one e^-.
Accept e for e^-.

14. (a) increasing cost of oil (relative to other energy sources);
limited supply (of petroleum);
other sources of energy available / alternative energy sources;
(use as a raw material) reduces/delays greenhouse gas/global warming/climate change problems;
concerns about greenhouse gases/climate change causing changes in behaviour */ OWTTE;*
Do not accept just "greenhouse gases/climate change".
products from raw materials can be recycled / fuels cannot be recycled;
increasing demand as raw material from continued economic growth/demand for wider variety of products;
more profit to be made (by using as raw material);
reduced availability of other sources of hydrocarbons; **[2 max]**
Accept political factors, such as "conflicts disrupting production".

(b) *phenol-methanal*: strong covalent bonds throughout 3D network / cross-linking;
Kevlar ®: weaker intermolecular forces/H-bonds/dipole-dipole/van der Waals' (between the chains); **[2]**

15. (a) biphenyl/planar ring structure makes molecule rigid/rod-shaped;
nitrile/cyano group makes molecule polar / allows orientation in an electric field / ensures alignment in common direction;
long hydrocarbon chain keeps molecules apart/prevents close packing/lowers melting point; **[2 max]**
*Award **[1 max]** for "chemically stable **and** rapid switching speed".*

(b) (polarized) light shone through film of liquid crystal;
ability to transmit (polarized) light depends on orientation (of molecules);
orientation can be controlled by (small) voltage/potential difference (across small film of material);
Accept current instead of voltage.

some areas can be dark/do not allow (polarized) light to pass **and** others light/allow (polarized) light to pass; **[3 max]**

(c) releases electrons **and** creates positive holes;
these separate between the n-type and p-type semiconductor;
creates a potential difference between the terminals / electron flow/current generated; **[2 max]**

16. (a) research/technology development at 1–100 nm (range); **[1]**
Accept answers referring to a scale within the specified range.

(b) *Sides:*
(atoms arranged in) hexagons
and
Ends:
(atoms arranged in) pentagons (and hexagons); **[1]**

(c) <u>strong covalent/C–C</u> bonding (in the walls of the nanotubes) / *OWTTE*; **[1]**

(d) possible toxicity of small (airborne) particles;
explosive / small size/large surface area means dangerously fast reactions;
unknown health effects / immune system/allergy concerns;
uncertain impact on environment;
lack of public awareness about dangers;

increasing economic disparity between developed and developing nations; **[2 max]**
Accept other valid concerns.

Option D — Medicines and drugs

17. (a) range of dosages/concentrations of drug (able to treat disease successfully) staying within safety limit / between effective/ED_{50} and toxic levels/LD_{50}; **[1]**
*Do **not** accept definition of therapeutic index (ratio of LD_{50}/TD_{50} to ED_{50}).*
Accept "lethal levels" for "toxic levels" even if laboratory animals are not referred to.

(b) adverse effects of drug / physiological/psychological effect other than that for which the drug was prescribed / secondary (undesired) effects of drug / *OWTTE*; **[1]**

(c) causes small bubbles (of gas) to coalesce into larger bubbles **and** be released as flatulence / anti-foaming agent / reduces bloating; **[1]**
Accept counteracts side-effects.

18. (a) *Advantage:*
relieves strong/severe pain / relieves pain caused by serious injury/cancer/surgery/heart attack / (intravenous so) faster acting;
Accept relieves anxiety / wide safety margin.
*Do **not** accept just "relieves pain".*

Disadvantages:
*Any two for **[2 max]** of:*
(profound) tolerance develops;
addictive/(physical) dependence/habit forming;
causes drowsiness / mental clouding / depression/mood changes / constipation / loss of appetite /depression of the respiratory centre / nausea / suppresses cough reflex / pupil (of the eye) constriction / kidney/liver disorders; **[3]**
*Do **not** accept other disadvantages, such as overdose and coma.*

(b) (i) morphine has (two) hydroxyl groups **and** diamorphine (heroin) has (two) ester groups; **[1]**
*Accept alcohol or hydroxy for hydroxyl but **not** hydroxide.*

(ii) ester group/diamorphine less polar / hydroxyl group/morphine more polar / diamorphine more soluble in non-aqueous systems/lipids/fats/fatty tissue / morphine less soluble in non-aqueous systems/lipids/fats/fatty tissue;

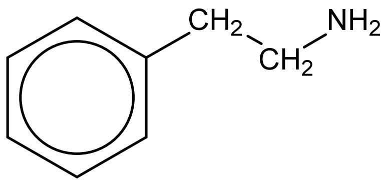
(ester group means) diamorphine crosses blood-brain barrier/into central nervous system/CNS/brain faster/more easily; **[2]**
*Award **[1 max]** for answers that correctly describe diamorphine/morphine but do not compare the two.*

19. (a) (i) $CH_3CH_2OH(aq) \rightarrow CH_3CHO(aq) + 2H^+(aq) + 2e^-$; **[1]**
Accept equilibrium sign, e for e^- and different representations of organic compounds (such as C_2H_6O and C_2H_4O).
Ignore state symbols.
*Do **not** accept $CH_3CH_2OH + [O] \rightarrow CH_3CHO + H_2O$ (since half-equation requested).*

(ii) (orange) dichromate(VI) ion/$Cr_2O_7^{2-}$/Cr(VI)/Cr^{6+} is reduced/converted to (green) chromium(III) ion/Cr(III)/Cr^{3+}; **[1]**

(b) absorption (of IR at 2950 cm^{-1}) by C–H bond;
(IR) absorption increases with/proportional to concentration / (IR) intensity compared to an empty/control cell; **[2]**
Accept area under peak/size of peak (on IR spectrum) can be used to measure ethanol concentration.

20. (a) (releases adrenaline so) increased brain activity/alertness/concentration / reduction in sleepiness/restlessness/insomnia; **[1]**
*Do **not** accept other effects, such as "increases heart rate", that are not related to the improvement of mental activity.*

(b) 

/ $C_6H_5CH_2CH_2NH_2$; **[1]**
Accept Kekulé representation of benzene ring.

21. (a) (i) prevent the formation of bacterial cell walls / interfere with chemicals/enzyme/transpeptidase needed by bacteria to form normal cell walls / inhibits cross-links developing in bacterial cell walls;
(osmosis) causes water to enter bacterial cell and cell bursts / cell wall weakens (making it more permeable to water) and bacterium bursts (and dies); **[2]**

(ii) C=O carbon is sp^2 hybridized **and** others are sp^3;
(normal) bond angles (120° and 109.5°) cannot be achieved in ring;
Accept bond angles in the ring are 90. **[2]**

(b) (i) only one enantiomer is active/has required effect / one enantiomer may have adverse effects; **[1]**
Accept stereo/optical isomer, but not just isomer.

(ii) chiral auxiliary attaches to non-chiral compound;
creates desired stereochemical conditions for reaction / ensures only one isomer is produced / *OWTTE*;
auxiliary removed/recycled after reaction (to leave desired product); **[3]**
*Award **[1 max]** for making the compound chiral/optically active / OWTTE.*

(c) change cell membrane to prevent viruses entering/attaching to cell;
alter cell's genetic material so virus cannot use it to multiply;
inhibit enzymes involved in replication/reverse transcriptase / stop enzyme activity inside the cell (and prevent the viruses from multiplying);
prevent replicated virus leaving the cell;
initiates apoptosis/death of cells infected by viruses;
mimic guanosine/base-sugar monomer in DNA/RNA formation inhibiting enzymes involved in replication; **[2 max]**

Option E — Environmental chemistry

22. (a) *Any one of:*

Gas	**and** Source
methane/CH_4	anaerobic decomposition of organic waste / bogs / marshes / animals / rice paddies / oil/gas fields;
nitrogen(I) oxide/ dinitrogen monoxide/N_2O *Accept nitrous oxide.*	bacterial action / combustion of biomass / artificial fertilizers/use of nitrogen based fertilisers;
chlorofluorocarbons/CFCs	propellants in aerosol sprays/cans / (old) refrigerators / air conditioners / solvents / foaming agents/plastic foams / fire extinguishers;
ozone/O_3	photochemical smog / interaction of sunlight with hydrocarbons and nitrogen oxides; *Accept electrical discharges.*
sulfur hexafluoride/SF_6	gaseous dielectric medium in electrical industry / inert gas for casting magnesium / filling for double-glazed windows / electrical generators / insulator used in electrical industrial applications;
nitrogen trifluoride/NF_3	(manufacture of) computer chips/circuits / (thin film) solar/photovoltaic cells / LCD televisions;

[1 max]

*Do **not** accept other gases such as SO_x and NO_x – generally reckoned to be insignificant.*

(b) (i) allows (higher frequency) radiation from sun/incoming radiation to pass unhindered;

long wavelength/infrared/IR radiation radiated/emitted by <u>Earth;</u>
*Do **not** accept reflected.*

(some IR radiation is) absorbed by greenhouse gases;
*Do **not** accept "trapped / blocked" or statements that refer to absorption of incoming IR radiation.*

causes (increased) vibration in bonds;
Accept "causes (increased) bond stretching/bending/deformations".

emits/re-radiates IR radiation (some of which returns to Earth); **[3 max]**
*Do **not** accept "heat/IR radiation reflects/bounces".*

(ii) ***Any two** for **[1]** of:*
abundance/concentration (in atmosphere)
strength/intensity/power of IR absorbance / ability to absorb heat radiation
lifetime/duration / rate of depletion/decomposition in atmosphere; **[1]**

(c)

Effect **and**	Consequence
increased mean global temperature	thermal expansion of oceans / melting of polar ice-caps/glaciers / changes in weather patterns / changes in yield/distribution/viability of crops / changes in distribution of pests/disease-carrying organisms / changes food chain / endangers animals/plants/insects;
increase/decrease/change of local/regional temperature / climate change	melting of polar ice-caps/glaciers / changes in weather patterns / changes in yield/distribution/viability of crops / changes in distribution of pests/disease-carrying organisms / floods / droughts / destruction of habitat/infrastructure / loss of life / changes food chain / endangers animals/plants/insects;
(CO_2 in atmosphere) decreases pH/increases acidity of oceans	destruction of coral / changes/endangers animals/plants/insects/food chain;
Accept thermal expansion of oceans	*rising sea levels / flooding (of low lying areas) / destruction of habitat/infrastructure;*
Accept melting of polar ice-caps/glaciers	*rising sea levels / flooding (of low lying areas) / destruction of habitat/infrastructure;*
Accept changes in precipitation / more extreme weather / more storms	*floods / droughts / destruction of habitat/infrastructure / loss of life;*

[3 max]

*Award **[1 max]** for three effects or consequences.*

23. (a) O_2 has double bond/bond order of 2 **and** O_3 has bond length between O–O and O=O/bond order of 1.5;
Accept "bond in O_2 stronger than in O_3" / OWTTE.

higher frequency (UV radiation) absorbed by O_2 / low frequency (UV radiation) absorbed by O_3; **[2]**
Accept correct answers phrased in terms of energy/wavelength rather than frequency.

(b) (i) $NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$;
$NO_2(g) \rightarrow NO(g) + O\bullet(g)$;
$NO_2(g) + O\bullet(g) \rightarrow NO(g) + O_2(g)$;
$NO_2(g) + O_3(g) \rightarrow NO(g) + 2O_2(g)$;
$O_3(g) + O\bullet(g) \rightarrow 2O_2(g)$; **[3 max]**
Accept representation of radicals without • if consistent throughout.
Ignore state symbols.

(ii) chlorofluorocarbons/CFCs **and**
propellants in aerosol sprays/cans / (old) refrigerators / air conditioners / solvents / foaming agents/plastic foams / fire extinguishers; **[1]**
Accept specific examples (eg, Freon/dichlorodifluoromethane/CF_2Cl_2 etc).

24. (a) amount/concentration of oxygen needed to decompose/oxidize organic/biological matter/waste in water;
in a specified time/5 days / at a specified temperature/ $20^{\circ}C$; **[2]**

(b) *multi-stage distillation:*
sea water is heated/boiled;
passed into an evacuated chamber/low pressure chamber;
sea water boils/evaporates / (dissolved) solids left behind/in solution;
steam is condensed/cooled by (pipes containing) incoming sea/cold water;

OR

reverse osmosis:
water moves from concentrated to dilute solution / water moves from lower $[H_2O]$ to higher $[H_2O]$;
high/~70 atm pressure;
through semi/selectively/partially permeable membrane;
(semi/selectively/partially permeable membrane) allows water but not ions/dissolved solids to pass through; **[3 max]**

Accept valid points communicated by means of diagrams.

(c) distance of facility from source of waste / transport costs;
cost/energy requirement to run the plant;
cost to build facility (to environmental/safety requirements);
possible use of generating electrical energy / supplying heating to homes; **[2 max]**
*Accept other reasonable **economic** arguments.*

25. (a) amount/number of exchangeable cations/cation sites;
per 100 g/unit of soil; **[2]**
*Award **[1 max]** for answers discussing exchangeable cations/cation sites / OWTTE.*

(b) oxidation/nitrification <u>by bacteria</u>;
$NH_4^+ + 2O_2 \rightarrow 2H^+ + NO_3^- + H_2O$ / $NH_4^+ + 2O_2 \rightarrow HNO_3 + H^+ + H_2O$; **[2]**
Accept $NH_4^+ + 3H_2O \rightarrow HNO_3 + 9H^+ + 8e^-$.

Option F — Food chemistry

26. (a) glycerol / propan-1,2,3-triol; **[1]**
Accept minor errors in naming, such as propane-1,2,3-triol.

(b) (i) kink/shape of *cis*-isomer prevents molecules packing closely together / reduces area of close contact / *OWTTE*;
so weaker intermolecular attractions/dispersion/London/van der Waals' forces; **[2]**
Accept converse argument based on trans-isomer.

(ii) hard to metabolize / accumulates in fatty tissue / difficult to excrete;
increases levels of LDL cholesterol / increases risk of heart disease; **[2]**
*Do **not** accept "increases level of bad cholesterol".*

(c) (i) *Initiation step:*
$RH \rightarrow R\bullet + H\bullet$;
Propagation steps:
$R\bullet + O_2 \rightarrow ROO\bullet$;
$ROO\bullet + RH \rightarrow R\bullet + ROOH$;
Termination step:
$R\bullet + R\bullet \rightarrow RR$ / $R\bullet + ROO\bullet \rightarrow ROOR$ / $ROO\bullet + ROO\bullet \rightarrow ROOR + O_2$; **[4]**
Accept $R\bullet + H\bullet \rightarrow R\text{–}H$.

(ii) reduce light levels (during storage);
minimize the amount of air (in headspace above oil) / airtight container; **[1 max]**
Accept store in refrigerator/at low temperature.

27. (a) *Similarity:*
phenol/phenolic structure / hydroxyl group attached to phenyl/benzene ring;
Accept "all contain a benzene ring/phenyl (group) / all contain hydroxyl".
*Accept alcohol/hydroxy for hydroxyl, but **not** hydroxide.*

Differences:
*Any two for **[2 max]** of:*
2-BHA and 3-BHA have ether group;
antioxidants (in data booklet) all have tertiary butyl group;
hydroxytyrosol and tyrosol have hydroxyl group (at end of carbon chain); **[3]**
Accept tyrosol and hydroxytyrosol have more than one hydroxyl group / OWTTE.
*Accept alcohol or hydroxy for hydroxyl but **not** hydroxide.*

Accept correct formulas (eg, C_6H_5OH / $–CH_2CH_2OH$ *or* $C_6H_5–$ / $–OH$*) instead of names.*

(b) inhibits formation of radicals / inhibits propagation of free-radical chain; **[1]**

28. (a) (i) absorption of violet/blue **and** orange/red; **[1]**
*Do **not** award the mark for answers mentioning giving out/emitting light.*

(ii) extensive conjugation/delocalization / extended system of conjugated double bonds/delocalized electrons; **[1]**
Accept "contains porphyrin/porphin ring".

(b) (i) multiple/conjugated C=C/carbon to carbon double bonds; **[1]**

(ii) light;
higher/increased temperatures;
metals / transition metal ions;
hydroperoxides / peroxides; **[2 max]**
Accept acidity/low pH.

(iii) fat-soluble **and** many non-polar groups/long non-polar chain; **[1]**
*Accept fat-soluble **and** absence of hydroxyl/OH/polar/H-bonding groups.*

(c) non-polar end/hydrophobic groups dissolve(s) in oil **and** polar end/hydrophilic groups dissolves in water/lemon juice;
Accept "interacts/bonds to" instead of "dissolves in".
Accept "soluble in both oil and water".

emulsifier holds liquid droplets as a dispersed system / *OWTTE*; **[2]**

29. rank groups/prioritise substituents based on atomic number;
C=O/highest atomic number is group 1;
lowest priority group/H points away from viewer;
other groups ranked 1 to 2 to 3 (read) clockwise; **[3 max]**

Option G — Further organic chemistry

30. (a) *Structure:*
hexagon with all sides equal / regular hexagon;
*Accept “**two** of angles equal” OR “planar/flat” OR “hexagonal”. (True for Kekulé structure!)*

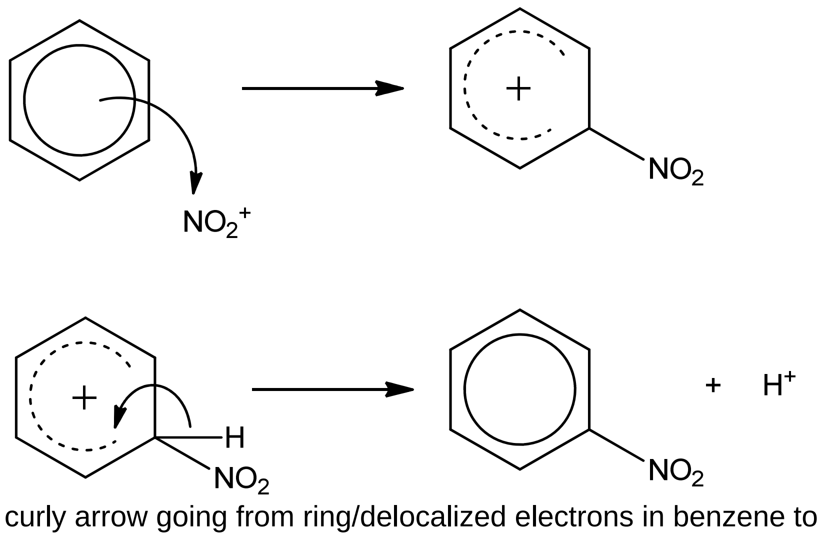
Bonding:
all (C–C) bonds equal strength / all (C–C) bonds have a strength between single and double bond / (C–C) bond orders all 1.5;
Accept "length" instead of "strength".
delocalized π-bond/electrons / resonance hybrid between two equivalent structures; **[3]**
Accept all C-atoms have one π-bond and three σ-bonds / sp^2 hybridization.

Give credit for correct responses given in the wrong section.

(b) (enthalpy of) hydrogenation much less (negative/exothermic)/more endothermic than predicted (for alternate single and double C–C bonds);
enthalpy of formation much less (positive/endothermic)/more exothermic than predicted (for alternate single and double C–C bonds);
(enthalpy of) combustion much less (negative/exothermic)/more endothermic than predicted (for alternate single and double C–C bonds); **[1 max]**
Accept opposite statements for alternate single and double C–C bonds.

(c) (i) concentrated sulfuric acid/H_2SO_4; **[1]**

(ii)



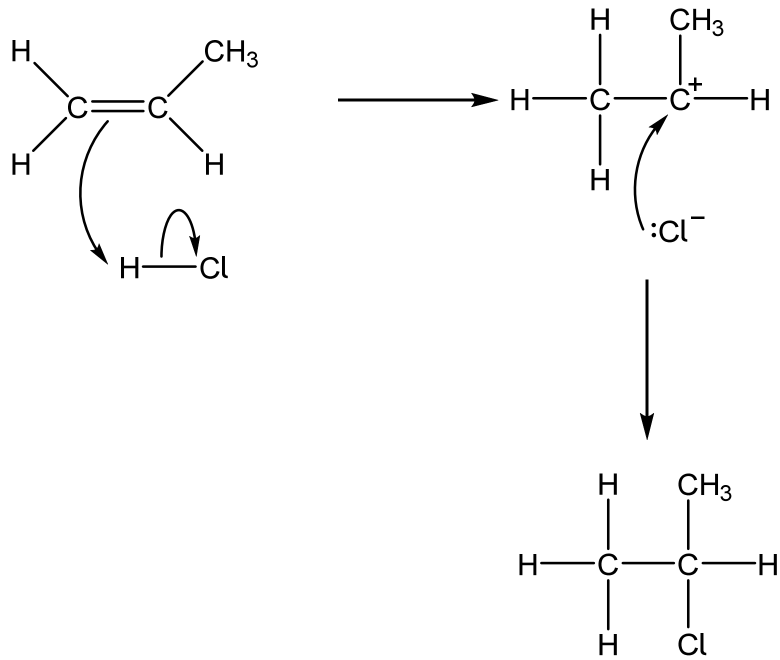
curly arrow going from ring/delocalized electrons in benzene to $^{+}NO_2$/NO_2^+;
carbocation with correct formula **and** positive charge on ring;
curly arrow going from C–H bond to benzene ring cation / curly arrow going from charge/oxygen lone pair on HSO_4^- to H being lost from intermediate;
formation of nitrobenzene **and** H^+/H_2SO_4 (if HSO_4^- referred to in M3); **[4]**
Accept mechanism with corresponding Kekulé structures.

(d) methylbenzene reacts faster/benzene reacts slower **and** methyl group electron donating/has +I effect;
*Do **not** accept "ring activating" instead of "electron donating".*

methylbenzene reacts faster/benzene reacts slower **and** stabilizes the carbocation intermediate / increases the electron density on the ring; **[2]**
Relative reactivity must be correctly mentioned once only.
Accept appropriate diagrams.

(e) nitrobenzene / chlorobenzene / benzoic acid; **[1]**
Accept any other compound with a deactivating group, attached to the benzene ring.

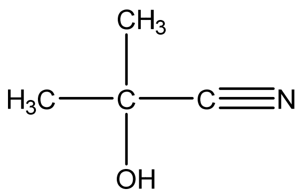
31. (a)



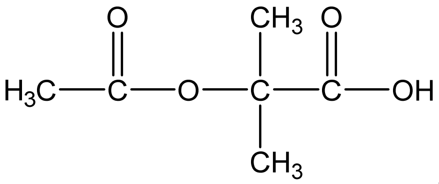
curly arrow going from C=C to H of HCl **and** curly arrow showing Cl^- leaving;
representation of carbocation (including position of positive charge);
curly arrow going from lone pair/negative charge on Cl^- to C^+;
formation of $CH_3CHClCH_3$; **[4]**
Mechanisms that lead to the minor product could gain all but the last mark.

(b) $CH_3CHBrCH_3$; **[1]**
Accept $CH_3CH_2CH_2Br$ if $CH_3CH_2CH_2Cl$ given in (a).

32. (a) (nucleophilic) addition-elimination / condensation; **[1]**

(b)  / $(CH_3)_2C(OH)CN$; **[1]**

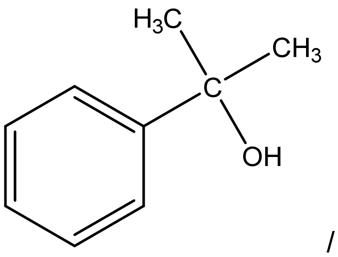
Accept full or condensed structural formula.

(c) (i)  / $CH_3COOC(CH_3)_2COOH$; **[1]**

Accept full or condensed structural formula.
Accept the anhydride produced by the acyl chloride reacting with the acid, then ECF for (ii).

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

(d) hydroxyl group/OH is electron withdrawing/has –I (inductive) effect;
stabilizes the anion formed / weakens the O–H bond (in the –COOH group); **[2]**

(e) (i)  / $C_6H_5C(CH_3)_2OH$; **[1]**

Accept full or condensed structural formula.

(ii) magnesium/Mg **and** bromobenzene/C_6H_5Br; **[1]**