



MARKSCHEME

May 2014

CHEMISTRY

Standard Level

Paper 3

*It is the property of the International Baccalaureate and must **not** be reproduced or distributed to any other person without the authorization of the IB Assessment Centre.*

Subject Details: Chemistry SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the options [**2 x 20 marks**]. Maximum total = [**40 marks**].

1. A markscheme often has more marking points than the total allows. This is intentional.
2. Each marking point has a separate line and the end is shown by means of a semicolon (;).
3. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.
4. Words in brackets () in the markscheme are not necessary to gain the mark.
5. Words that are underlined are essential for the mark.
6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.
7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect).
8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.
10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.
11. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the markscheme. Similarly if the formula is specifically asked for, unless directed otherwise in the markscheme do not award a mark for a correct name.
12. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the markscheme.
13. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

Option A — Modern analytical chemistry

Penalize incorrect bond linkages (eg, $\text{CH}_2\text{—HO}$ instead of $\text{CH}_2\text{—OH}$) and/or missing hydrogens once only in option at first occurrence.

1. (a)

<i>Purpose</i>	<i>Analytical Technique</i>
<i>Determining the level of ethanol in the breath of a driver of a vehicle</i>	infrared (spectroscopy)/IR <i>Allow gas (liquid) chromatography/GLC.</i>
<i>Determining the concentration of chromium in seawater</i>	atomic absorption (spectroscopy)/AA/AAS
<i>Body scanning to diagnose the autoimmune disease, multiple sclerosis</i>	(^1H /proton) nuclear magnetic resonance/NMR / magnetic resonance imaging/MRI <i>Allow PET.</i>
<i>Testing for the presence of volatile compounds</i>	chromatography / gas chromatography/GC <i>Allow HPLC / IR (spectroscopy).</i>

[2]

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

- (b) *Absorption spectra:*
 (when radiation is passed through sample) atom/ion/molecule becomes excited / electrons raised to higher energy level/state / *OWTTE*;
 only specific frequencies/wavelengths absorbed / black lines on a coloured background / spectrum shows where absorption happens, such as dips (in the IR spectrum) / *OWTTE*;

Emission spectra:
 (energy given out by) excited atom/ion/molecule moves to lower energy state / excited electrons move to lower energy level/ground state / *OWTTE*;
 colours same as those missing from absorption spectra / coloured lines on black background / only specific frequencies/wavelengths emitted / *OWTTE*;
Difference may also be shown by two different representations of spectra.

[4]

2. (a) *Stationary phase:*
silica/SiO₂/silicon dioxide / alumina/Al₂O₃/aluminium oxide;

Specific mobile phase:

any named suitable solvent or mixture of solvents (for example, ethyl ethanoate); [2]

Allow water.

Do not allow just solvent.

- (b) substances easier to remove/recover from TLC plate for identification;
components that separate can be obtained pure;
results more easily reproduced;
(much) faster (than paper chromatography);
(particles finer in TLC than pores in paper so) better separation;
greater efficiency / greater resolving power (since less diffusion of spots);
less tailing / more precise R_f (values);
more sensitive / can be used for small samples;
broad range of materials as sorbents;

[1 max]

(c) (i)

<i>Compound</i>	<i>R_f value</i>
<i>A</i>	0.28
<i>B</i>	0.81

Award [1] for both correct.

[1]

- (ii) B is more soluble in solvent/mobile phase / B is less polar than A / B is less strongly adsorbed onto stationary phase;

Accept B is non-polar.

Do not allow "greater attraction/affinity to solvent" without reference to solubility.

[1]

3. (a) *I: O-H and II: C=O;*
Do not allow CO for C=O.
Allow OH for O-H.

[1]

- (b) three hydrogens in same (chemical) environment / CH₃/methyl (group);

[1]

- (c) *Award [2] for all three correct, [1] for any two correct.*

m/z = 45 :

COOH⁺ / CO₂H⁺ / C₂H₅O⁺ ;

m/z = 17 :

OH⁺ ;

m/z = 15 :

CH₃⁺ ;

Penalize missing + once only.

[2]

- (d) $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ / $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$; [1]
Allow full or condensed structural formula.
- (e) (i) $\text{CH}_2(\text{OH})\text{CH}_2\text{COOH}$ / $\text{HO}(\text{CH}_2)_2\text{CO}_2\text{H}$; [1]
Allow full or condensed structural formula.
- (ii) different integration trace / integration trace 1:2:2:1 (in **Y**) / different chemical shift values / *OWTTE*; [1]
- (f) (i) 102; [1]
- (ii) 4; [1]

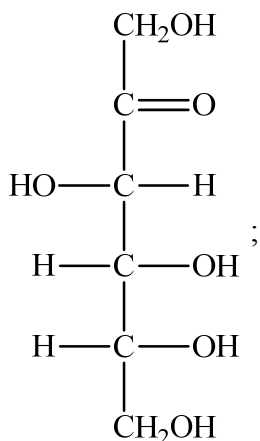
Option B — Human biochemistry

Penalize incorrect bond linkages (eg $\text{CH}_2\text{-HO}$ instead of $\text{CH}_2\text{-OH}$) and/or missing hydrogens once only in option at first occurrence.

4. (a) (source of) energy;

[1]

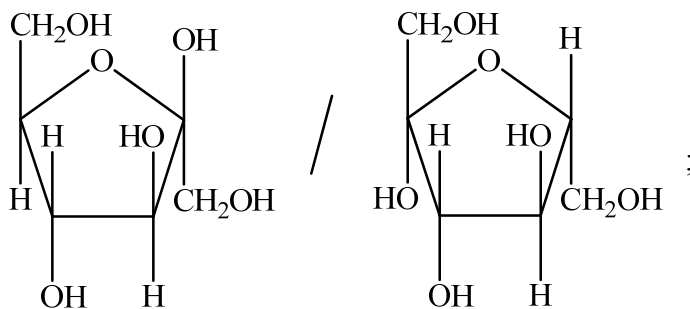
(b) (i)



[1]

Accept any six-carbon linear structure in which the second carbon is a carbonyl and there is one OH on all other carbons.

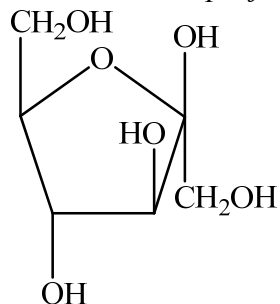
(ii)

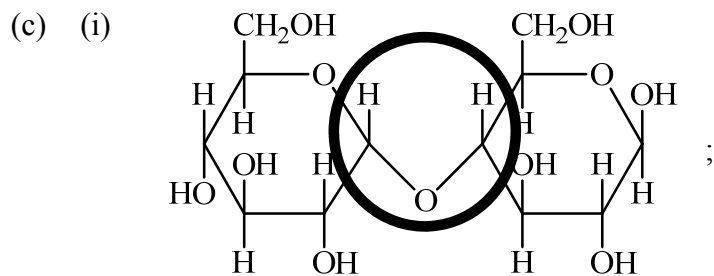


[1]

Correct orientation of groups is required.

Allow Haworth projection, ie,





[1]

Circle must include the two carbon atoms.

- (ii) α -glucose;
Allow glucose.

[1]

- (iii) lactose is made up of galactose and glucose while maltose is made up of two glucose molecules;
positions of OH groups on far left and far right carbons are interchanged / *OWTTE*;
lactose contains a beta (1,4 glycosidic) link while maltose contains an alpha (1,4 glycosidic) link;
position of H on left-side of 1,4 glycosidic link differs in both maltose and lactose / *OWTTE*;

[2 max]

5. (a) (i) mass (in g) of I_2 reacting with 100 g of fat/oil/substance/lipid; [1]
Allow amount/number of mol of I_2 reacting with 1 mol of fat/oil/substance/lipid.

(ii) $\frac{8.50}{253.4} / \frac{8.50}{254} / 3.35 \times 10^{-2}$ (mol);

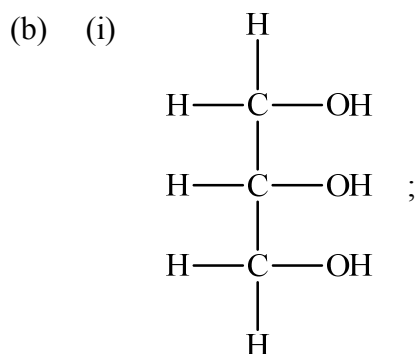
$$\left(\frac{3.35 \times 10^{-2}}{1.12 \times 10^{-2}} \right) = 3 \text{ (C=C)}; \quad [2]$$

OR

$$\frac{8.50}{1.12} \times 10^{-2} / 759 \text{ (g } I_2 \text{ react with one mol of fatty acid);}$$

$$\left(\frac{759}{254} \right) = 3 \text{ (C=C)};$$

M2 can only be awarded if M1 is correct.



Accept any correct representation.

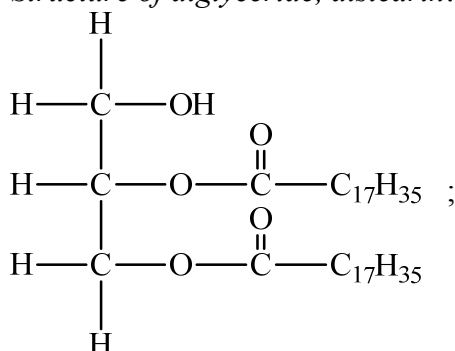
- (ii) *Name of functional group of triglyceride:*
 ester
Allow triester.
Do not allow $-\text{COO}-$.

and

Other product formed:
 water/ H_2O ;

[1]

(c) Structure of diglyceride, distearin:



Accept a structure with OH in middle also.

Name of other product:

stearic acid/octadecanoic acid / stearate/octadecanoate;

[2]

Name required.

Do not allow stearin.

(d) fats have fewer oxygens than carbohydrates (of same molar mass) / fats less oxidized;

Allow converse statements for carbohydrates.

a larger change in carbon's oxidation number occurs when fats are oxidized / more energy is used in breaking the bonds in carbohydrates than the bonds in fats;

[2]

6. (a) impotence / urination problems / smaller testes / lower sperm count / enlarged breasts / decrease in testosterone production / reduction in secondary male characteristics / OWTTE;

[1]

(b) clenbuterol does not contain 4-ring structure /steroid backbone/three six-membered rings **and** a five-membered ring;

[1]

Allow "does not contain steroid structure".

(c) testosterone and progesterone both contain an alkene/C=C **and** a C=O/ carbonyl;

Allow ketone instead of carbonyl.

Ignore any reference to methyl groups.

OH/hydroxyl present (only) in testosterone;

[2]

Do not allow hydroxide.

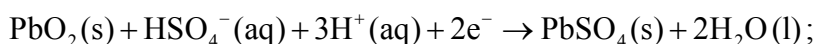
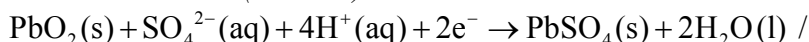
Allow alcohol/hydroxy.

Option C — Chemistry in industry and technology

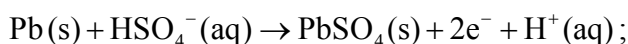
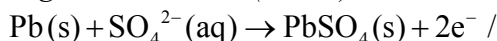
7. (a) (i) *Production of aluminium:*
 electrolysis of molten alumina/aluminium oxide/ Al_2O_3 ;
- Role of cryolite:*
 (molten) cryolite (saves money due to) lower operating temperature / solvent with a lower melting point (than aluminium oxide);
Accept lowers the melting point of aluminium oxide.
- Negative electrode (cathode):*
 $\text{Al}^{3+}(\text{l}) + 3\text{e}^- \rightarrow \text{Al}(\text{l})$;
- Positive electrode (anode):*
 $2\text{O}^{2-}(\text{l}) \rightarrow \text{O}_2(\text{g}) + 4\text{e}^-$; **[4]**
- Allow e for e⁻.*
Ignore state symbols.
Penalize use of equilibrium sign once only.
*Award **[1 max]** for M3 and M4 if correct equations are given but at the wrong electrodes.*
- (ii) no electricity / electricity not widely available before 1900; **[1]**
- (b) (i) to control/improve properties / alloys are stronger/more durable/less reactive/less malleable/less ductile than pure metals; **[1]**
- (ii) only a small number of metals have low densities / many low density metals are too reactive / alloys need presence of other metallic atoms of slightly different size (few metals like this); **[1]**
- (c) (purification of ore produces) waste Fe_2O_3 /iron(III) oxide/red mud;
 carbon dioxide/ CO_2 from burning electrodes;
 environmental impacts of power generation;
 aluminium production a significant contributor to global warming;
 mining the ore damages the landscape/local ecology;
 generation of fluorides/polyfluorinated carbons/fluorine containing waste products; **[1]**

8. (a) (i) *Lead-acid:*

Positive electrode (cathode):



Negative electrode (anode):



[2]

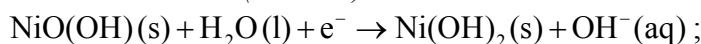
Allow e for e⁻ throughout.

Ignore state symbols.

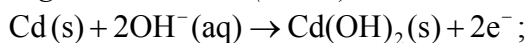
Award [1 max] if correct equations are given but at the wrong electrodes.

(ii) *NiCad:*

Positive electrode (cathode):



Negative electrode (anode):



[2]

Allow e for e⁻ throughout.

Ignore state symbols.

Award [1 max] if correct equations are given but at the wrong electrodes.

(b) *Similarity:*

(both) convert chemical energy to electrical energy / (both are) voltaic cells;

Differences:

Award [2 max] for any two.

rechargeable batteries employ reversible reactions while fuel cells have irreversible reactions;

fuel cells work non-stop while rechargeable batteries take time to recharge;

fuel cells need a constant supply of reactants/fuel while rechargeable batteries do not need any other substances;

fuel cells convert energy **and** rechargeable batteries store energy;

fuel cell products must be constantly removed but not for rechargeable batteries;

fuel cells are less polluting/more expensive/weigh less/last longer (than lead-acid rechargeable batteries);

fuel cells have inert/Pt electrodes/components while lead-acid rechargeable

batteries have active/non-inert/Pb and PbO₂ electrodes;

fuel cells run at higher temperatures than rechargeable batteries;

fuel cells are less portable than rechargeable batteries / fuel cells require pumps/cooling systems while rechargeable batteries do not;

[3 max]

Award [2 max] if three valid points (one similarity and two differences) are given without comparison and [1 max] if two valid points are given without comparison.

9. (a) $C_{20}H_{42} \rightarrow C_8H_{18} + C_2H_4 + C_{10}H_{20}$ / $C_{20}H_{42} \rightarrow C_8H_{18} + 6C_2H_4$
Accept any correctly balanced equation that includes octane and at least one ethene molecule as products.
correct reactants **and** products;
balanced equation; [2]
M2 can only be scored if M1 is correct.
- (b) (i) *Award [1] for any two.*
HDPE has higher mp;
HDPE is more rigid / less flexible;
HDPE is stronger; [1]
Accept opposite statements for LDPE.
- (ii) HDPE has straight chain **and** LDPE has branched chain / LDPE has more branched chains; [1]
- (c) more valuable for (cracking to provide) chemical precursors/petrochemicals / may be cracked to produce same substances now obtained from lighter fractions / *OWTTE*; [1]

Option D — Medicines and drugs

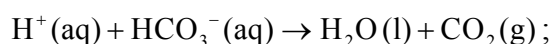
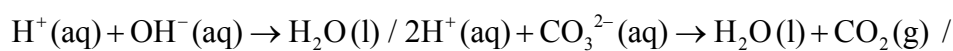
10. (a) *Compound:*
hydrochloric acid/HCl;

Strong or weak acid:
strong (acid);

[2]

- (b) *Type of reaction:*
neutralization;
Accept acid-base.

Ionic equation:



[2]

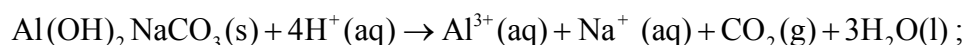
Accept equations such as $\text{Mg}(\text{OH})_2(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$.

Ignore state symbols.

H_3O^+ or H^+ may be used in the equation.

Do not allow the inclusion of spectator ions.

- (c) $\text{Al}(\text{OH})_2\text{NaCO}_3(\text{s}) + 4\text{HCl}(\text{aq}) \rightarrow \text{AlCl}_3(\text{aq}) + \text{NaCl}(\text{aq}) + \text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l}) /$



correct reactants **and** products;

correct state symbols **and** balanced;

[2]

M2 can only be awarded if M1 is correct.

- (d) (i) excess gas in stomach/intestinal tract can cause bloating (which is prevented by addition of anti-foaming agent) / prevents flatulence / *OWTTE*;

Ignore any reference to heartburn.

[1]

- (ii) dimethicone/hexamethyldisiloxane / simethicone/poly(dimethylsiloxane);

Do not accept alginates.

[1]

11. (a) intercepts pain stimulus at source / inhibits release of substances/prostaglandins that cause pain/swelling/fever; [1]
- (b) (i) ionic compound (which dissociates); [1]
- (ii) $C_9H_7O_4^-(aq) + H^+(aq) \rightarrow C_9H_8O_4(aq)$; [1]
Ignore state symbols
Ignore arrow.
- (c) (i) phenyl/benzene ring;
Do not allow just benzene or arene or the formula C_6H_6 .
- ester; [2]
Do not allow $-COO-$ or carbonyl/ CO .
- (ii) hydroxyl / phenol; [1]
Allow alcohol/hydroxy but not hydroxide.
Do not allow $-OH$.
- (iii) *Award [1] for any two short-term advantages from:*
 strong/powerful (pain reliever);
 fast-acting / effective;
 has a wide safety margin;
 can quickly stop diarrhoea;
 can be used in cough mixtures/medicines / antitussive properties;
 works effectively with paracetamol/acetaminophen;
- Award [1] for any two long-term disadvantages from:*
 (regular use) can lead to addiction/dependence/withdrawal symptoms;
 tolerance can lead to toxic dosages;
 can result in depression / apathy;
 can cause mental health problems;
 can result in constipation;
 can result in sterility/sexually related problems;
 memory loss;
 serious health risk to babies who are breastfed; [2 max]
- Award [1 max] for one correct advantage and one correct disadvantage.*

12. (a)

<i>Method</i>	<i>Example</i>
parenteral / injection	local anesthetics / dental injections / (some) vaccines / strong analgesics
rectal/via rectum / suppositories / via anus	antibiotic / hemorrhoids (treatments) / digestive illnesses
transdermal / skin patches / topical	nicotine patches / estrogen/estradiol / hormone treatments / ointments
eye/ear drops	sight/eye/ear infections / antibiotic / antibacterial drug/solution

[2]

Allow any reasonable example.

Award [1] for any two correct methods.

Award [1] for any two correct corresponding examples.

*Award [1 max] for any correct method **and** correct corresponding example.*

Award [1 max] if two types of injection method (eg, intramuscular, subcutaneous) are given with an example.

- (b) *Award [1] for any two from:*
 addiction / withdrawal symptoms
 lung/mouth/throat/larynx cancer
 emphysema
 (chronic) bronchitis
 high blood pressure
 increased risk of heart disease/angina
 coronary thrombosis/clotting (of the blood)
 peptic ulcers
 atherosclerosis

[1 max]

- (c) more points of possible hydrogen bonding in caffeine / more polar / OWTTE;

[1]

Option E — Environmental chemistry

13. (a) carbon monoxide/CO / volatile organic compounds/VOCs / particulates; [1]
 Allow carbon dioxide/CO₂.

(b)

<i>Fuel</i>	<i>Method to reduce emissions</i>
<i>Diesel</i>	particulate filters/DPF/soot traps / catalytic converter/diesel-oxidation catalyst/DOC / recirculation of exhaust gases / low-sulphur diesel;
<i>Petrol (gasoline)</i>	catalytic converter / lean burn engine/adjusting fuel:air ratio / recirculation of exhaust gases / soot-collecting exhaust / thermal exhaust reactor;

[2]

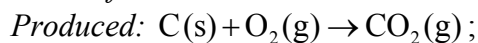
Award [1 max] for stating “more efficient engines” for both diesel and petrol/gasoline.

- (c) combustion of (sulfur containing) coal;
 metal extraction/smelting (of sulfide ores);
 sulfuric acid/H₂SO₄ plants; [2]

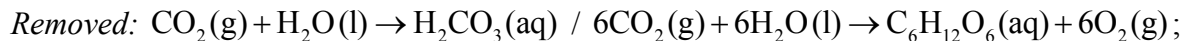
14. infrared/IR radiation emitted by (warm) Earth;
 water in clouds is a greenhouse gas / O-H bonds(in water) absorb infrared/IR radiation;
 Infrared/IR radiation is absorbed and re-radiated by water (less total loss of IR); [2 max]
Award [1 max] for discussing clouds acting as heat insulators.

15. (a) process by which acidic (substances) leave atmosphere/return to Earth / *OWTTE*; [1]
Do not allow acid rain.

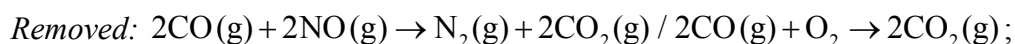
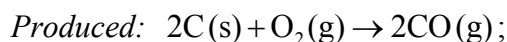
- (b) *Oxide of carbon:*



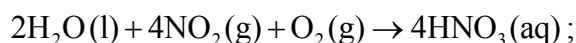
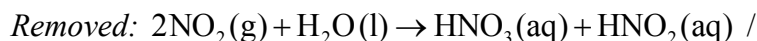
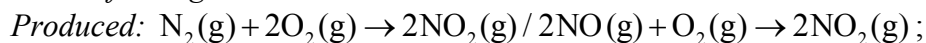
Accept a correctly balanced equation for the combustion of a hydrocarbon fuel.



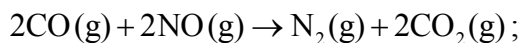
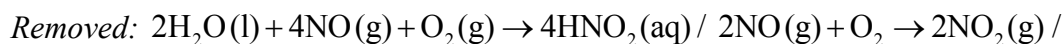
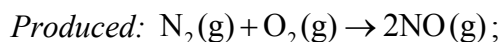
OR



Oxide of nitrogen:



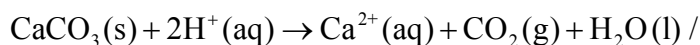
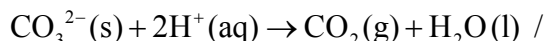
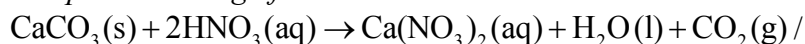
OR



[4]

Ignore state symbols.

- (c) shells become thinner as some of the calcium carbonate shell reacts / *OWTTE*;
Accept "dissolving of marine carbonate shells".



[2]

Ignore state symbols.

Allow equations with H_2SO_3 and HNO_2 .

Do not accept H_2CO_3 instead of H_2O and CO_2 .

16. (a) (i) harvesting / intensive farming / monoculture/repeatedly growing same crop / heavy tillage / over-grazing / acid leaching; [1]
- (ii) leave land fallow / use fertilizers/manure/compost / rotate crops / graze animals / nitrogen-fixing plants; [1]
- (b) irrigation waters contain dissolved salts / poor drainage; salts left behind when water evaporates; [2]
- (c) provides source of nutrients;
improves structural stability;
influences water retention properties;
alters soil thermal properties;
enhances soil's ability to buffer pH changes;
binds to contaminants reducing their effects;
contributes to the soil's cation-exchange capacity; [2 max]

Option F — Food chemistry

17. (a) *Food*:
substance intended for (human) consumption;

Nutrient:
obtained from food **and** used by body for metabolism/to provide energy/regulate growth/repair body tissues; [2]

(b)

<i>Molecule</i>	$ \begin{array}{cccccccc} & \text{OH} & \text{H} & \text{OH} & \text{OH} & & & \\ & & & & & & & \\ \text{OHC} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{CH}_2\text{OH} & & \\ & & & & & & & \\ & \text{H} & \text{OH} & \text{H} & \text{H} & & & \end{array} $	$\text{CH}_3\text{CH}_2(\text{CH}=\text{CHCH}_2)_3(\text{CH}_2)_6\text{COOH}$
<i>Present in food</i>	<i>Honey</i>	<i>Sardines</i>
<i>Two named functional groups</i>	aldehyde hydroxyl <i>Award [2] for all four correct.</i> <i>Award [1 max] for two or three correct.</i> <i>Allow alcohol but not hydroxide for hydroxyl.</i> <i>Allow carboxylic/alkanoic acid but not carbonyl for carboxyl.</i> <i>Names required.</i>	alkene carboxyl
<i>Protein, carbohydrate or fatty acid</i>	carbohydrate	and fatty acid; [3]

- (c) *Saturated fat*: no carbon-carbon double bonds/no C=C/all single carbon-carbon bonds/ all C-C **and** *Unsaturated fat*: carbon-carbon double bonds/C=C/alkene groups; [1]
Mention of carbon-carbon or alkene necessary for mark.

- (d) (i) *Structural formula*:
 $\text{CH}_3(\text{CH}_2)_4\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$ /
 $\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}_2\text{CH}_2\text{CH}_2(\text{CH}_2)_6\text{COOH}$;
Catalyst: nickel/Ni / palladium/Pd / platinum/Pt / copper/Cu / zinc/Zn; [2]

- (ii) margarine; [1]

- (iii) decrease (blood) levels of HDL/high-density lipoprotein cholesterol (which protects from heart disease) / increase levels of LDL/low-density lipoprotein cholesterol (increasing risk of heart disease) / less easily digested/metabolized / leads to blocked arteries; [1]

- (iv) carbohydrate / disaccharide;
Allow sucrose / sugar. [1]

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

- (b) (i) *One from each for [1]:*

<i>Antioxidant</i>	<i>Food source</i>
Selenium	shellfish / cod / shrimp / tuna / halibut / salmon / scallops / red meat / eggs / grain / mustard seeds / chicken / turkey / mushrooms (crimini/ shiitake) / garlic / brazil nuts <i>Allow fish.</i>
β -carotene	and carrots / romaine lettuce / squash / broccoli / sweet potatoes / tomatoes / kale / cantaloupe melon / peaches / apricot / spinach / thyme <i>Allow bananas.</i>

Other sources may be possible please check with your team leader if in doubt.

- (ii) phenol / hydroxyl / phenyl / benzene ring; [1]
Do not allow hydroxide, benzene or arene.
Allow alcohol for hydroxyl.
Name required.
- (iii) (species) with unpaired electron / resulting from homolytic bond fission; [1]
- (iv) unpleasant flavours (in fats) due to oxidation / (perception of flavours in fats perceived as off due to) disagreeable smell/taste/texture/appearance / *OWTTE*; [1]

19. (a) dye is (always) water-soluble but pigment is not / *OWTTE*; [1]
Some reference must be made to water for mark.

- (b) (i) vitamin B₂/riboflavin is water-soluble but vitamin A/retinol is fat-soluble so large doses may result in high levels of toxicity / *OWTTE*; [1]
Allow "vitamin B₂ may be eliminated more easily" or "vitamin A is stored".

- (ii) β -carotene is yellow **and** chlorophyll is green;
Allow orange/red for β -carotene.
According to the colour wheel in the question, the complementary colour for violet is yellow green and for red it is bluish green. Allow these colours.

β -carotene absorption in violet region (so yellow/orange/red is complementary colour) **and** chlorophyll absorption in red region (so complementary colour is green);

Allow [1 max] for reference to one compound alone ie, " β -carotene absorption in violet region so yellow/orange/red is complementary colour" or "chlorophyll absorption in red region so complementary colour is green".

[2]

Option G — Further organic chemistry

Penalize incorrect bond linkages (eg, $\text{CH}_2\text{-HO}$ instead of $\text{CH}_2\text{-OH}$) and/or missing hydrogens once only in option at first occurrence.

20. (a) planar **and** six-membered/hexagonal ring;
Accept suitable diagram showing either ring structure with circle representing delocalization or a Kekulé-type structure.
Allow flat for planar.

all carbon-carbon bond lengths equal/0.140 nm / all carbon-carbon bond lengths between single/0.154 nm and double/0.134 nm / all carbon-carbon bonds have same strength;

all bond angles 120° /equivalent;
Allow "all carbons sp^2 (hybridized)".

delocalization of electrons / OWTTE; **[3 max]**
Allow "p orbital/ π electrons extend over all carbon atoms".

- (b) benzene does not (readily) undergo addition reactions / benzene more likely to undergo substitution reactions / benzene does not decolourize bromine water;

only one isomer of 1,2-disubstituted benzene (eg, 1,2-dibromobenzene) exists (if there were alternate single and double bonds these would be two);

there are three isomers of type $\text{C}_6\text{H}_4\text{X}_2$, so if there were alternate single and double bonds there would be four;

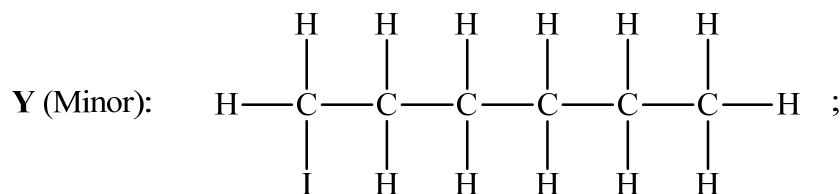
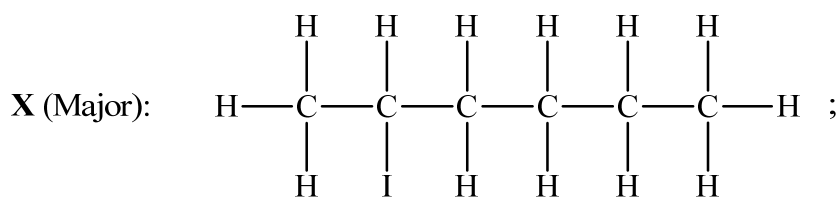
benzene not hydrogenated by hydrogen (and a platinum catalyst) under usual conditions that hydrogenate an alkene;
Do not award this mark if high pressure is stated.

benzene not oxidized by potassium manganate(VII)/potassium permanganate/ KMnO_4 ; **[1 max]**
Allow other suitable named oxidizing agent.

Accept appropriate thermochemical evidence.

21. (a) (i) $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$; [1]
Accept either full or condensed structural formula.
- (ii) elimination / dehydration; [1]
Do not accept condensation.
- (iii) concentrated sulfuric is an oxidizing agent; [1]
Allow "side reactions may occur with concentrated sulfuric".
Allow converse statement for phosphoric acid.
Do not allow "phosphoric acid has more protons than sulfuric".
- (b) (phenol is) stronger (acid);
no positive inductive effect in phenol / positive inductive effect (of alkyl group) in butan-1-ol (strengthening OH bond, making release of H^+ difficult) / lone pair on oxygen/negative charge on phenoxide anion/ $\text{C}_6\text{H}_5\text{O}^-$ can delocalize/spread round benzene ring (so charge density decreases) / negative charge localized on oxygen atom in butan-1-ol; [2]

22. (a) (i)

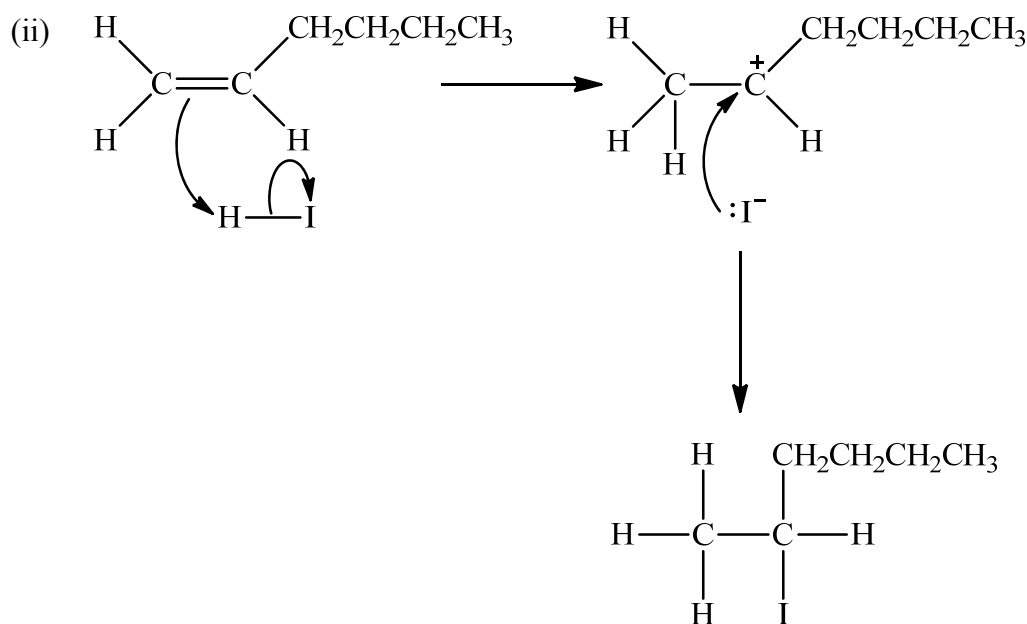


[2]

All bonds must be drawn for both structures.

Award [1 max] if condensed formulas (or partially condensed) are given.

Award [1 max] if correct structures given but X and Y reversed.



curly arrow going from C=C to H of HI **and** curly arrow showing I leaving;
representation of secondary carbocation;

curly arrow going from lone pair/negative charge on I^- to C^+ ;

Allow *ecf* from (a) (i).

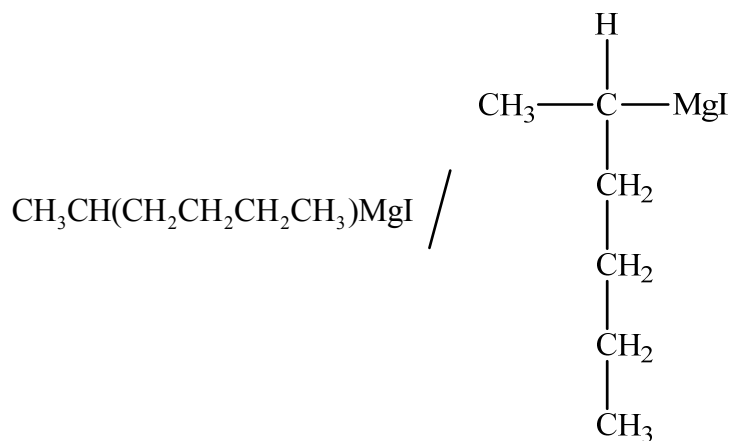
[3]

(iii) positive charge is stabilized by more/two electron-releasing alkyl groups/by inductive effect of two alkyl groups / secondary carbocation more stable than primary carbocation because of greater number of electron-releasing/inductive effect of alkyl groups / *OWTTE*;

No *ecf* from (a)(i)

[1]

(b) (i)



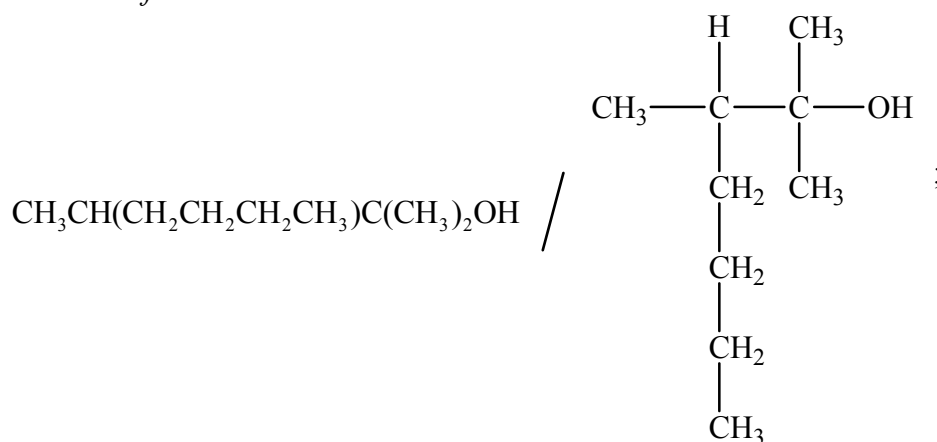
[1]

Allow full or condensed structural formula.

(ii) solvent should be dry/anhydrous / non-polar/ether solvent;

[1]

(iii) Structural formula:



[1]

Allow full or condensed structural formula.

Class of compound:

alcohol;

[2]

Do not allow hydroxyl/hydroxide/hydroxy.

(iv) carbon dioxide/CO₂;

[1]