



# **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**

1. (a) *Emission spectrum*: coloured lines **and** *Absorption spectrum*: black/dark lines;

**OR**

*Emission spectrum*: lines **and** *Absorption spectrum*: continuous; [1]  
 Allow “*Emission spectrum*: electrons emit energy as they drop to lower energy levels **and** *Absorption spectrum*: electrons absorb energy as they are promoted to higher energy levels” / OWTTE.

(b)

Type of spectroscopy	Type of atomic or molecular process	Region of electromagnetic spectrum
$^1\text{H}$ NMR	(change in) nuclear spin;	radio;
IR	bond vibrations / stretching <b>and</b> bending of bonds;	infra-red
visible/UV/ atomic absorption/AA	electronic transitions	visible/UV

[4]

For M4 both visible/UV/atomic absorption/AA for type of spectroscopy **and** region of EMS required.

- (c) to determine the amount/percentage/concentration of the element present; [1]

2. (a)  $\text{C}_2\text{H}_5\text{I}^+$  ;  
 $\text{I}^+$  **and**  $\text{C}_2\text{H}_5^+$  ; [2]  
 Penalize once only if the + sign is missing.

- (b) 108 **and** 110;  
 79 **and** 81;  
 29; [3]

3. (a) *Spot 1*:  $R_f = 0.75$  **and** *Spot 2*:  $R_f = 0.25$  ; [1]

- (b) two amino acids have the same  $R_f$  value; [1]

- (c) change the polarity/make-up of the solvent / use a different solvent; [1]  
 Accept two way (paper) chromatography.

4. *Student A / Infrared*

propanoic acid can be distinguished from the other two by the (broad) absorption at  $2500-3300\text{cm}^{-1}$  / due to  $-\text{OH}$  absorption in carboxylic acids;

not easy to distinguish between methyl ethanoate and ethyl methanoate because all absorb at  $1700-1750\text{cm}^{-1}/\text{C}=\text{O}$  /  $1050-1410\text{cm}^{-1}/\text{C}-\text{O}$  /  $2850-3100\text{cm}^{-1}/\text{C}-\text{H}$  / because they have same functional groups;

can be distinguished from the pattern in the fingerprint region / by comparing with spectra of known samples;

*Student B /  $^1\text{H}$ NMR*

methyl ethanoate can be distinguished from the other two as it will have two peaks of equal area (due to the two  $-\text{CH}_3$  groups);

propanoic acid and ethyl methanoate cannot be distinguished as both have three peaks / peaks in the ratio of 1:2:3;

chemical shift is also required to distinguish them;

[6]

*Absorption value or name of functional group required for M1 and M2.*

**Option B — Human biochemistry**

5. (a) energy (released by granola) =  $(500 \times 4.18 \times 9.5) = 19855 \text{ (J)} / 2.0 \times 10^4 \text{ (J)}$ ;

$$\text{energy released (in kJ per 100 g)} \left( \frac{19855}{1000} \times \frac{100}{1.13} = \right) 1757.079;$$

$$= 1.8 \times 10^3 \text{ (kJ per 100 g);}$$

*Allow 1800 (kJ per 100 g).*

*Award [3] for correct final answer.*

*Award [2 max] for 1760 (kJ per 100 g).*

*Remember to allow ECF.*

[3]

(b) (i) plant material/carbohydrates/cellulose not digested/hydrolysed (by enzymes secreted by (human) digestive tract) / *OWTTE*;

*Allow more precise definitions such as “(plant) material/carbohydrates not digested in (human) small intestine with complete/partial fermentation in (human) large intestine” / OWTTE.*

[1]

(ii) *Any two of the following conditions.*

diverticulosis;

irritable bowel/IBS;

constipation;

obesity;

Crohn’s disease;

higher risk of colon cancer;

hemorrhoids;

diabetes mellitus/Type 2 diabetes;

[2 max]

6. (a) Allow any two for [1] from:  
 octanoic (acid);  
 lauric (acid);  
 stearic (acid); [1]  
 Allow molecular or structural formula (either full or condensed).
- (b) (i)  $\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH} + \text{I}_2 \rightarrow \text{CH}_3(\text{CH}_2)_7\text{CHI}-\text{CHI}(\text{CH}_2)_7\text{COOH}$ ; [1]  
 Allow  $\text{C}_{17}\text{H}_{33}\text{COOH} + \text{I}_2 \rightarrow \text{C}_{17}\text{H}_{33}\text{I}_2\text{COOH} / \text{C}_{18}\text{H}_{34}\text{O}_2 + \text{I}_2 \rightarrow \text{C}_{18}\text{H}_{34}\text{I}_2\text{O}_2$ .
- (ii) amount of oleic acid =  $\left(\frac{1.00}{282.52}\right) 3.54 \times 10^{-3}$  (mol) = amount of  $\text{I}_2$  required;  
 volume of  $1.00 \text{ mol dm}^{-3}$  solution =  $3.54 \text{ (cm}^3\text{)}$ ; [2]  
 Award [2] for correct final answer.
- (c) (i) X: carboxyl;  
 Allow carboxylic acid.  
 Accept fatty acid. [2]  
 Y: hydroxyl;  
 Allow alcohol/alkanol/hydroxy but not hydroxide.  
 Award [1 max] if X and Y are reversed.
- (ii) consider C=C bonds in chain;  
 Accept unsaturation in chain, but not just double bonds.  
 length of carbon chain; [2]  
 Accept reasons such as close packing, no kink in molecule, stronger van der Waals /vdW/London/dispersion forces/LDF/intermolecular forces/instantaneous/temporary induced dipole-induced dipole forces / larger surface area (of contact).
- (d) fewer number of oxygen atoms in fats (compared to carbohydrates of similar molar masses) / fats less oxidized (compared to carbohydrates so more energy given off from oxidation) / OWTTE; [1]  
 Accept converse reasoning.
- (e) Similarities:  
 Award [1 max] for one similarity:  
 both unsaturated;  
 Allow both contain C=C/carbon to carbon double bond but not just double bond or COOH/carboxyl group (since acid stated in stem).  
 both have first (carbon to carbon) double bond/C=C on C9;  
 both have cis-configuration of (all) C=C (fragments);
- Differences:  
 Award [1 max] for one difference:  
 linoleic acid has  $\omega - 6$  (first) C=C **and** linolenic acid has  $\omega - 3$  (first) C=C;  
 linoleic acid has 2 C=C **and** linolenic acid 3 C=C / linolenic acid has one additional C=C; [2]  
 If either of these last two points are scored award a total of [2] as C=C similarity implied but award [1 max] only for "more unsaturated".

7. (a) molecule contains polar/OH/hydroxyl/NH/amino/COOH/carboxyl groups / molecule forms hydrogen bonds with water / *OWTTE*; [1]  
*Accept polar molecule so dissolves in water.*  
*Allow class (eg, carboxylic acid, amine etc.) if stated instead of functional groups.*
- (b) (i) xerophthalmia / retinitis pigmentosa/RP; [1]  
*Accept condition such as dry eyes associated with xerophthalmia or condition such as night blindness associated with retinitis pigmentosa.*
- (ii) vitamin A is fat-soluble/water-insoluble / vitamin A can be stored/accumulate in fat cells leading to fatality / excess vitamin A causes hypervitaminosis which can be fatal / *OWTTE*; [1]  
*Do not allow "vitamin A when consumed in large quantities can be poisonous", unless storage/accumulation in fat cells stated.*



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

8. (a) viscous / varied composition / complex mixture / has to be broken down into more usable substances / *OWTTE*; **[1]**

(b) *Award [1] for a general comparative statement in relation to using crude as an energy source **and** as a chemical feedstock. Examples might be:*

diesel/petrol/gasoline useful as energy source but burning hydrocarbons can result in global warming/pollution / *OWTTE* **and** chemical feedstock/crude oil based raw materials for other products / *OWTTE*;  
*Accept other reasonable examples of energy sources (tar, asphalt, waxes).*

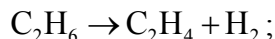
*Award [1 max] for any two:*

plastics/polymers;  
 solvents;  
 cosmetics;  
 dyes;  
 food additives;  
 detergents;  
 pharmaceuticals;  
 drugs/medicines;

**[2]**

(c) (i) *Type of cracking:*  
 steam;

*Chemical equation:*



*One reaction condition:*

high temperature range / low pressure;

**[2 max]**

*Allow any temperature if specified in the range 800–1400 °C/1073–1673K .*

*Award [2] for all three correct, [1] for any two correct.*

(ii) fuel (eg, in space vehicles) / to make fertilizer (on reaction with nitrogen) / margarine manufacture / reduction of metal ores;

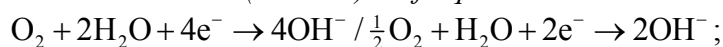
**[1]**

*Do not apply ECF from (i).*

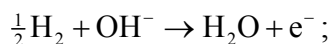
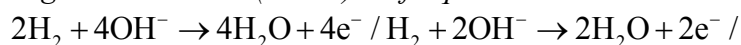
*Accept other reasonable answers.*

9. (a) chemical (energy) to electrical (energy); [1]

(b) (i) *Positive electrode (cathode) half-equation:*



*Negative electrode (anode) half-equation:*



[2]

*Award [1 max] if correct half-equations are given but incorrect electrodes.*

*Allow e instead of e<sup>-</sup>.*

*Penalise use of reversible arrow once only in 9 (b)(i) and 11 (a).*

(ii)  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l}) / \frac{1}{2}\text{O}_2(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) ;$

[1]

*State symbols required.*

*Allow H<sub>2</sub>O(g).*

(iii) allows flow of ions/H<sup>+</sup>/protons (from anode/negative electrode to cathode/positive electrode) / prevents reactants mixing/moving from one compartment to another / salt bridge / prevents flow of electrons through membrane / OWTTE;

[1]

(iv) storage/transport difficulties of gases / potentially explosive/hydrogen is flammable / needs constant supply of fuel / can contain heavy metal(s) / often operated at high temperature / low power to mass ratio / susceptible to poisoning due to impurities in fuel / OWTTE;

[1]

*Allow a named gas (hydrogen or oxygen) for storage/transport difficulties.*

*Allow problems related to corrosion.*

*Accept answers based on ethanol and methanol fuel cells (but needs to be stated) such as difficult to use in cold weather/less clean product (CO<sub>2</sub>) formed.*

10. (a) (i) (LCs are) fluids that exhibit molecular orientation/orderly molecular arrangement **and** A; [1]  
*Accept LCs show properties of liquids and crystals simultaneously and A.*
- (ii) I: no, since ionic (so high mp) / lacks long axis;  
*Allow no since it is not a molecule/not rod-shaped.*
- II: yes, since has long axis present (so limits ability of molecules to pack lowering mp);  
*Allow yes since rod-shaped.*  
 has polar functional group / is polar (increasing intermolecular interactions) / (planar/flat) benzene ring present (assists stacking);
- III: no, since lacks long axis; [4]  
*Allow no since non-polar.*  
*Allow no since not rod-shaped.*  
*Award [1 max] for stating II only will show LC behaviour OR I: No, II: Yes and III: No.*  
*Award [2 max] if one correct reason is given for each substance but LC behaviour is either incorrect or not given.*  
*Award [3 max] if correct reasons are given for all three substances, but LC behaviour is either incorrect or not given.*
- (iii) (free) rotation about carbon-carbon single bonds (hence greater flexibility) so octane molecules not rod-shaped / *OWTTE*; [1]  
*Do not allow mark for non-polar (molecule) only.*
- (b) (i) *Thermotropic*: pure substances **and** *lyotropic*: solutions / *thermotropic*: show LC behaviour over limited temperature range (between solid and liquid states) **and** *lyotropic*: shows LC behaviour at certain concentrations; [1]
- (ii) **X**: yes **and** **Y**: no **and** **Z**: yes; [1]  
*Award mark if no is stated only for Y or yes is only stated for X and Z.*

**Option D — Medicines and drugs**

11. (a) paracetamol blocks transmission of pain at source;  
*Accept paracetamol inhibits prostaglandin release in the brain.*
- codeine blocks (receptor sites in) the brain from receiving pain signals; [2]  
*Accept central nervous system/CNS instead of brain.*
- (b) codeine contains a hydroxyl group;  
*Allow alcohol/hydroxy but not hydroxide.*
- codeine contains one methoxy group/two ether groups;  
*Allow codeine contains one additional ether group but not codeine contains the ether group.*
- diamorphine contains ester/acetoxy/ethanoate group(s); [3]  
*Names required not functional group formulas.*  
*Allow acetyl group.*
- (c) aspirin may cause ulceration/internal bleeding/allergic reactions/Reye's syndrome / paracetamol (acetaminophen) does not cause ulceration/internal bleeding/allergic reactions/Reye's syndrome; [1]  
*Do not accept general statements such as aspirin has more side effects or paracetamol (acetaminophen) is safer.*
- (d) prevents (the recurrence of) heart attack/stroke / reduces ability of blood to clot; [1]
- (e) codeine/strong analgesic (in Solpadol<sup>®</sup>) is addictive/habit-forming / *OWTTE*; [1]
12. (a)  $\text{Mg}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{MgCl}_2 + 2\text{H}_2\text{O}$  ;  
 $\text{Al}(\text{OH})_3 + 3\text{HCl} \rightarrow \text{AlCl}_3 + 3\text{H}_2\text{O}$  ;  
 $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$  ; [3]  
*Accept  $\text{H}_2\text{CO}_3$  for  $\text{H}_2\text{O}$  and  $\text{CO}_2$ .*
- (b) (i) amount of  $\text{Mg}(\text{OH})_2 = \left( \frac{0.400}{(24.31 + 32.00 + 2.02)} = \frac{0.400}{58.33} \right) 6.86 \times 10^{-3}$  (mol)  
**and** amount of  $\text{Al}(\text{OH})_3 = \left( \frac{0.306}{(26.92 + 48.00 + 3.03)} = \frac{0.306}{77.95} \right) 3.93 \times 10^{-3}$  (mol) ;
- amount of HCl reacting =  $(2 \times 6.86 \times 10^{-3}) + (3 \times 3.93 \times 10^{-3}) = 2.55 \times 10^{-2}$   
(mol) so volume of  $1.00 \times 10^{-2}$  HCl = 2.55 (dm<sup>3</sup>) ; [2]  
*No ECF from (a) if formulas of  $\text{Mg}(\text{OH})_2$  or  $\text{Al}(\text{OH})_3$  are incorrect.*  
*Allow integer values for atomic masses.*  
*Award [2] for correct final answer.*

(ii) amount of  $\text{CaCO}_3 = \left( \frac{1.000}{(40.08 + 12.01 + 48.00)} = \frac{1.000}{100.09} \right) 9.99 \times 10^{-3} \text{ (mol)};$

amount of  $\text{HCl}$  reacting =  $(2 \times 9.99 \times 10^{-3}) = 2.00 \times 10^{-2} \text{ (mol)}$  so volume of  $1.00 \times 10^{-2} \text{HCl} = 2.00 \text{ (dm}^3\text{)};$

[2]

*Allow integer values for atomic masses.*

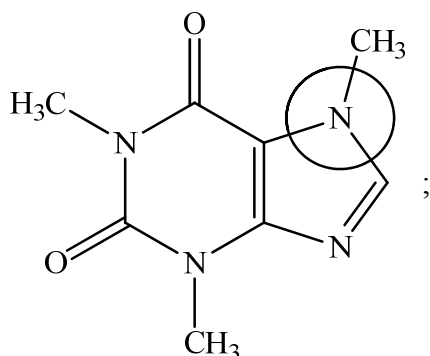
*Award [2] for correct final answer.*

*Penalize incorrect answer based on same units mistake once only in 12 (b) (i) and (ii).*

- (c) anti-foaming agent / reduces bloating / causes small bubbles (of gas) to coalesce into larger bubbles **and** be released as flatulence;

[1]

13. (a)



[1]

*Circle must enclose the correct nitrogen with three bonds.*

*Circle should not include  $\text{CH}_3$  on the nitrogen atom.*

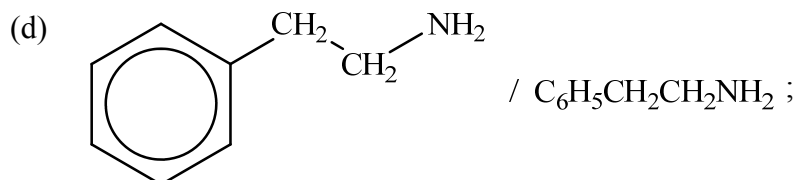
*Allow circle around nitrogen of imine group.*

- (b) makes a person want to urinate / *OWTTE*;

[1]

- (c) primary amine contains one R-/alkyl group bonded to the N atom **and** tertiary amine contains three R-/alkyl groups attached to the N atom;

[1]



[1]

*Penalize missing hydrogen atoms.*

**Option E — Environmental chemistry**

14. (a) greenhouse gases are transparent to/allow passage of short(er)-wavelength/  
high(er)-energy radiation/UV light from the Sun / *OWTTE*;  
greenhouse gases absorb long(er)-wavelength/IR radiation from the Earth / *OWTTE*;  
(part of) absorbed radiation is re-radiated back to the Earth / *OWTTE*; **[3]**  
*Do not accept reflected or trapped.*
- (b) *Award [2] for any of the following combinations:*
- (i)  $\text{N}_2\text{O}$ ;
- (ii) combustion/burning of biomass / nitrogenous/artificial/synthetic fertilizers /  
bacterial action;
- OR**
- (i)  $\text{SF}_6$ ;
- (ii) electronics industry / electrical switches / production of magnesium /  
gas-insulated substations;
- OR**
- (i)  $\text{NF}_3$ ;
- (ii) electronics industry / manufacture of semi-conductors / LCDs/liquid-crystal  
displays / thin-film solar cells / solar panels / chemical lasers;
- OR**
- (i)  $\text{SF}_5\text{CF}_3$ ;
- (ii) (by-product from  $\text{SF}_6$  in) high-voltage equipment / discharge / by-product of  
fluorochemical manufacture; **[2]**
- (c) *Award [1] for any two of the following:*  
melting of polar ice-caps/glaciers;  
changes in yield and distribution of crops / changes in agriculture/biodiversity /  
changes in habitats;  
droughts / desertification / flooding / decreased water quality due to flooding /  
lack of fresh drinking water / changes in precipitation;  
*Allow climate change.*
- rising sea-levels / thermal expansion of oceans / decreased dissolved oxygen /  
changes in distribution of pests and disease-carrying organisms / increased spread  
of diseases by insects/mosquitos moving to new areas / chance of malaria; **[1]**

15. (a) *Advantages of landfill:*  
 good for dealing with large volumes of waste / land when filled can be used for building purposes / no separation of rubbish/garbage required / cheap / can be expanded easily (where the land is available) / *OWTTE*;  
*Do not accept "no air pollution".*

*Disadvantages of landfill:*  
 poisonous/toxic chemicals can be produced / heavy metal (ions) leaching into drinking water supplies/source of underground pollution (soil or water) / often odours occur in immediate environment / non-biodegradable plastics/polymers may not be broken down / unsightly / takes up land (where land is expensive/unavailable) / occupies large area / *OWTTE*;  
*Do not allow "produces methane/CH<sub>4</sub>/greenhouse gas" (since given in stem).*

*Advantages of incineration:*  
 reduces volume of waste (only ash remains) / odour-free (stable) compounds produced / energy source (so can reduce energy cost) / produces slag/ash residues which can be used in building / *OWTTE*;  
*Do not accept "no land pollution".*

*Disadvantages of incineration:*  
 high construction costs / can form dioxins/toxic/poisonous gases/vapours/CO/carbon monoxide / needs energy (to run plant) / adds to greenhouse effect (due to carbon dioxide/CO<sub>2</sub> generated) / chlorinated compounds/polymers/plastics can generate hydrochloric acid/HCl resulting in acid rain;  
*Do not accept the advantage of one being the disadvantage of the other.*

[4]

*Do not accept general statements without support.*

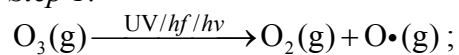
- (b) (i) swamps/marshes / rice fields/paddies / livestock manure/ruminant from cows/sheep / anaerobic microbial activity in lakes/ponds; [1]
- (ii)  $2\text{CH}_4(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}(\text{g}) + 4\text{H}_2\text{O}(\text{g})$  /  $\text{CH}_4(\text{g}) + 1.5\text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g}) + 2\text{H}_2\text{O}(\text{g})$ ; [1]  
*State symbols must be included.*  
*Allow H<sub>2</sub>O(l).*  
*Accept any other pollutant, such as methanal: CH<sub>4</sub>(g) + O<sub>2</sub>(g) → HCHO(g) + H<sub>2</sub>O(g).*

16. (a) *Aerobic:* elements in organic material oxidized **and** *Anaerobic:* elements in organic material reduced; [1]

(b) (i)  $\left(\frac{1.50 \times 10^{-4}}{4} =\right) 3.75 \times 10^{-5} \text{ (mol)}$ ; [1]

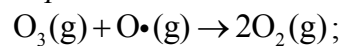
(ii)  $\left(\frac{3.75 \times 10^{-5} \times 1000 \times 32.00}{200} =\right) 6.00 \times 10^{-3} \text{ (g dm}^{-3}\text{)}$ ; [1]

17. (a) *Step 1:*



*UV not needed for mark (since given in question).*

*Step 2:*



[2]

*Ignore state symbols.*

*Allow O instead of O• if consistent throughout.*

(b)  $\text{C}_2\text{F}_6$  still has low reactivity/toxicity/flammability like CFCs;

$\text{C}_2\text{F}_6$  has (very) strong C–F bond (so stable to UV);

$\text{C}_2\text{F}_6$  cannot produce chlorine radicals/ $\text{Cl}\cdot/\text{Cl}$ ;

*Do not allow “ $\text{C}_2\text{F}_6$  contains no chlorine(s)” or general answers such as “does not react with ozone”.*

$\text{C}_2\text{F}_6$  has a long lifetime/half-life/ $t_{1/2}$ ;

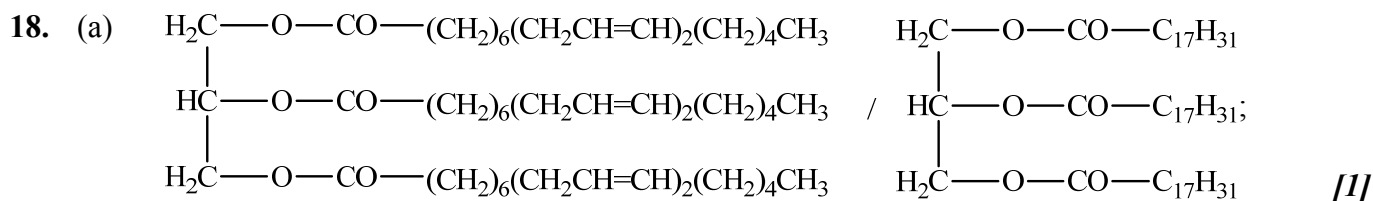
*Allow specific time such as greater than 10,000 years.*

$\text{C}_2\text{F}_6$  also a greenhouse gas/absorbs IR;

[3 max]



**Option F — Food chemistry**



*Do not accept R for C<sub>17</sub>H<sub>31</sub>.*

*Penalize for incorrect bond connectivity.*

(b) water/H<sub>2</sub>O ; [1]

(c) double bonds cause a “kink” in the hydrocarbon chain / unsaturated hydrocarbon chains cannot pack so closely together (as saturated); attractive forces/London/dispersion/van der Waals/vdW/LDF/ /instantaneous/temporary induced dipole-induced dipole forces between the molecules are weaker / less energy required to overcome the attraction between the molecules; [2]

(d) addition of hydrogen/H<sub>2</sub> / hydrogenation; heat **and** catalyst/Zn/Cu/Ni/Pd/Pt; [2]  
*Accept any temperature in range 140 – 225 °C .*

(e) *Advantages:*  
decreases rate of oxidation / makes it more stable / slows rancidification / has longer shelf life;  
greater energy released per gram / *OWTTE*;  
controls hardness/plasticity/stiffness; [2 max]

*Disadvantages:*  
increase risk of heart disease / increase low-density/LDL cholesterol;  
does not contain essential/omega-3/omega-6 fatty acids;  
hydrogenated fats might contain *trans*-fatty acids; [2 max]

19. (a) (i) antimicrobial agent / delays microbial/bacterial growth/mould / stops fermentation/slows down enzymatic reactions; [1]

(ii) fixing colour / inhibits microbial/bacterial growth/mould; [1]  
*Do not allow curing meats.*

(b) carbonyl; [1]  
*Accept ketone.*

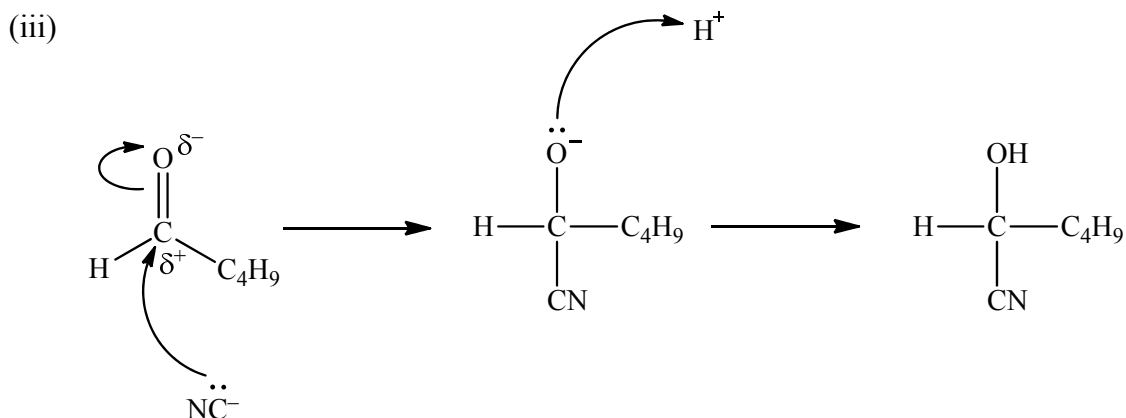
20. (a) C;  
it is the only one that lies within the visible region of the spectrum / it is in the yellow/green region so the complementary colour is blue/violet; **[2]**  
*Award M2 only if M1 is correct.*
- (b) oxidation;  
temperature;  
pH change;  
presence of metal ions;  
light / photo-oxidation; **[2 max]**
21. increased risk of allergic reactions;  
potential risk to health of changing the diet / risk of changing natural nutritional quality of foods;  
unknown consequences of mixing GM DNA with unmodified DNA / unknown effects of GM organisms breeding with unmodified organisms;  
risk of passing antibiotic resistant genes to harmful organisms;  
as yet unknown effect on food chain;  
loss of variety of species;  
susceptibility to “superbugs” / *OWTTE*;  
GM seeds controlled by a few companies so farmers lack choice/economically dependent / *OWTTE*; **[3 max]**

### Option G — Further organic chemistry

Penalize missing hydrogen atoms or incorrect bond linkage (eg, NH-C) once only in this option.



Ignore missing brackets.



curly arrow going from lone pair/negative charge on C in  $NC^-$  to carbonyl C **and** curly arrow going from double bond to O;

Do not allow curly arrow originating on N of  $NC^-$ .

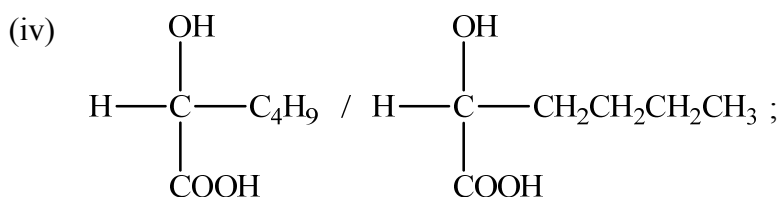
Partial charges not required.

representation of intermediate anion with negative charge on O;

Lone pair on O not required.

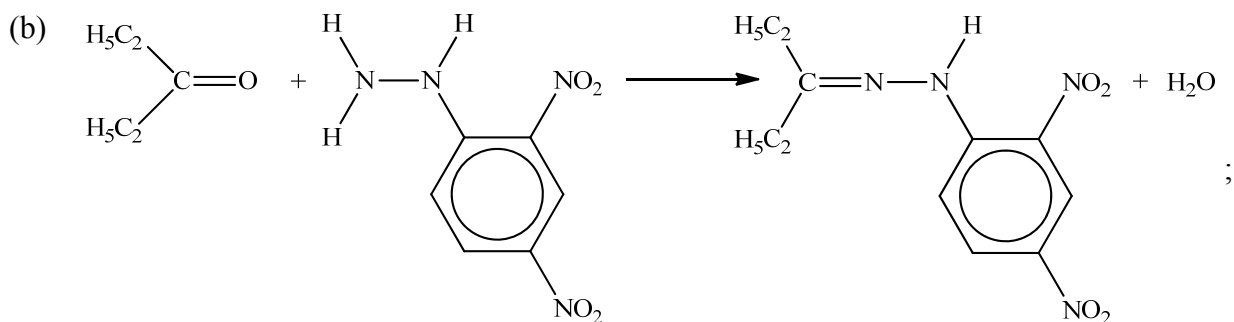
curly arrow going from lone pair/negative charge on O of intermediate anion to  $H^+$ ;

[3]



2-hydroxyhexanoic acid;

[2]



Award [1] for correct formula of pentan-3-one and [1] for correct equation.

Accept condensed formula for 2,4-DNPH.

[2]

23. (a) ethanal/CH<sub>3</sub>CHO **and** water/H<sub>2</sub>O;  
butan-2-ol/ CH<sub>3</sub>CH<sub>2</sub>CH(OH)CH<sub>3</sub>;  
*Accept 2-butanol.*  
*Ignore missing brackets.*
- phosphoric acid/H<sub>3</sub>PO<sub>4</sub> **and** heat; [3]  
*Allow sulfuric acid/H<sub>2</sub>SO<sub>4</sub> but not just H<sup>+</sup>.*  
*Accept any temperature in the range 100–200°C .*
- (b) **EITHER**  
magnesium/Mg **and** dry/ether/inert solvent;  
propylmagnesium bromide/CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>MgBr;  
*Accept bromo(propyl)magnesium.*  
*Ignore missing brackets.*
- carbon dioxide/CO<sub>2</sub> **and** water/H<sub>2</sub>O;
- OR**
- potassium cyanide/KCN/any other inorganic cyanide;  
*Accept cyanide ions/CN<sup>-</sup>.*
- butanenitrile/CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CN;  
*Accept systematic names such as butyronitrile or propyl cyanide or cyanopropane.*
- acid (solution)/H<sup>+</sup>(aq)/H<sub>3</sub>O<sup>+</sup>(aq) **and** heat/reflux; [3]  
*Accept any temperature in the range 50–300°C .*  
*Do not penalise if (aq) state omitted.*
24. (a) C<sub>2</sub>H<sub>5</sub>NH<sub>2</sub> + H<sub>2</sub>O ⇌ C<sub>2</sub>H<sub>5</sub>NH<sub>3</sub><sup>+</sup> + OH<sup>-</sup> ; [1]  
*Accept → in place of ⇌.*
- (b) non-bonding/lone pair of electrons on the N atom (enables proton/H<sup>+</sup> acceptance)  
/ OWTTE; [1]
- (c) two C<sub>2</sub>H<sub>5</sub>/alkyl groups exert a greater inductive/+ effect than one / OWTTE; [1]  
*Accept “cation formed is more stable due to increased charge dispersion”.*
- (d) (C<sub>2</sub>H<sub>5</sub>)<sub>3</sub>NH<sup>+</sup> / [(C<sub>2</sub>H<sub>5</sub>)<sub>3</sub>NH]<sup>+</sup> ; [2]  
tetrahedral;
-