N15/4/CHEMI/SP3/ENG/TZ0/XX/M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2015

Chemistry

Standard level

Paper 3

19 pages

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.

Option A — Modern analytical chemistry

1. (a) each (type of) bond absorbs a specific frequency/wavelength/wavenumber (of IR radiation);
bonds absorb radiation that has same frequency as their natural frequency of vibration;
(frequencies/wavenumbers associated with) troughs/peaks/region (in IR spectrum) allow identification of bonds (present in molecule); ***[2 max]***

(b) (O–H) bond length changes / bonds stretch;
bond angle changes / molecule bends;
change in molecular/bond polarity/dipole (moment); ***[3]***
*Allow **[1 max]** for M1 and M2 for only stating "vibrations".*
M1 and M2 can be awarded for diagrams of the H_2O molecule and correct arrows.

(c) compound **A**;
contains C=O corresponding to the absorption at (about) 1760 cm^{-1}/ 1700–1750 cm^{-1} (from data booklet);
Accept any specific value in the range 1700–1780 cm^{-1} or any range given between 1680 cm^{-1} and 1820 cm^{-1}.

contains OH (hydrogen bonding) of a carboxylic acid corresponding to the absorption at (about) 3000 cm^{-1}/2500–3300 cm^{-1} (from data booklet) / does not contain OH in alcohol corresponding to absorption in the range 3200–3600 cm^{-1} (from data booklet); ***[3]***
Accept any specific value in the range 2800–3200 cm^{-1}.

*Award **[1 max]** for answers choosing compound **B** because it contains C=O and OH.*

(d) compound **C**: (is the only one that) has 6 signals;
compound **A**: has 5 signals with ratio of areas 3:2:2:2:1;
compound **B**: has 5 signals with ratio of areas 3:3:2:1:1; ***[3]***

The numbers in the ratios can be in any order.
Accept "peaks" for "signals".

*Award **[1 max]** for M2 and M3 for stating "**A** and **B** have 5 signals each".*
*Award **[2 max]** for stating "**A** and **B** have 5 signals each **and C** has six signals".*

(e) $m/z = 57 : CH_3CH_2CH_2CH_2^+/C_4H_9^+$;
$m/z = 102 : CH_3CH_2CH_2CH_2COOH^+/C_4H_9COOH^+/C_5H_{10}O_2^+$; ***[2]***
Penalize missing + charge once only.

2. (a) identification of metal (ions) in water/solutions/blood/urine/soil/plants/foods/pharmaceuticals/oils;
determination of the concentration of metal (ions) in water/solutions/ blood/urine/soil/plants/foods/pharmaceuticals/oils; ***[1 max]***
Accept specific metal ions or specific examples.
Accept "detection" for "identification" or "determination".

(b) *Fuel:*
forms a combustion mixture;
Accept "creates a high temperature / produces heat".
Accept "(produces a flame that) atomises sample".
Do not accept just "vaporizes sample".

Monochromatic detector:
determines absorbance/intensity of light absorbed (at each wavelength) / compares the intensity of the beam passing through the sample with the reference beam (for each wavelength) / converts the intensity of light (absorbed) into an electrical signal; ***[2]***
Accept "amount of absorption" or "amount of light absorbed" instead of "intensity of light absorbed".
Do not accept just "detects absorbance/absorption".

3. (a) *Absorption spectra:*
electrons absorb a photon/light/wavelength/frequency/energy/radiation **and** move to higher energy level(s);
Accept "excited state(s)" for "higher energy level(s)".

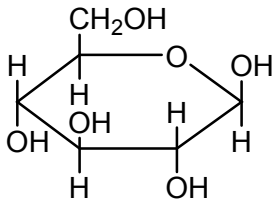
Emission spectra:
(excited) electrons move down to lower energy level(s) **and** release a photon/light/wavelength/frequency/energy/radiation; ***[2]***
Accept "state" for "level" throughout.

*Award **[1 max]** if the movement between energy levels is described correctly but the involvement of a photon/light/wavelength/frequency/energy/radiation is omitted.*
Accept suitable diagrams.

(b) electric discharge is passed through the sample / high voltage/potential applied (under reduced pressure) / sample is heated strongly;
sample emits a photon/light/wavelength/frequency/radiation/energy that is passed through a prism/diffraction grating (to separate the wavelengths); ***[2]***

Option B — Human biochemistry

4. (a) (i)



; ***[1]***

(ii) (α-glucose) OH/hydroxyl on C_1 is below the ring; ***[1]***
Accept "alcohol/hydroxy" for "OH/hydroxyl" but not "hydroxide". Penalize this once only on paper.

(b) (β-)1,4 glycosidic; ***[1]***
Accept "(ß-)1,4 glycoside".
Accept "1-4" for "1,4".

5. (a) vitamin C more soluble as it has four/several/more OH/hydroxyl groups;
forms hydrogen bonds with water; ***[2]***
Accept converse argument for vitamin D.
Accept "alcohol/hydroxy (groups)" for "OH/hydroxyl (groups)" but not "hydroxide".
Penalize this only once on paper.

*Award **[1 max]** for stating "Vitamin C is water-soluble **and** Vitamin D is fat-soluble".*

(b) (eating) fresh foods/fruits / foods rich in vitamins/minerals;
adding nutrients missing in commonly consumed foods / (vitamin/mineral) fortification;
providing nutritional supplements;
Accept any specific examples.

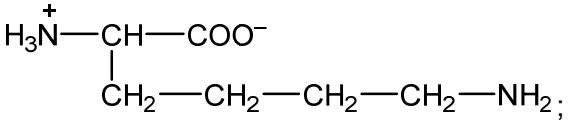
genetic modification of food;
educating the population in healthy eating/taking a balanced diet / better labelling of food with more information on products / *OWTTE*; ***[3 max]***

6. (a)

Type of interaction		*Atoms or groups joined by the interaction*
hydrogen bonds	**and**	OH/C=O/NH **and** OH/NH (in polar side chains) ;
vdW/van der Waals'/London/dispersion forces/instantaneous induced dipole-induced dipole	**and**	non-polar/hydrophobic/hydrocarbon side chains ;
disulphide bridges	**and**	bonds between two S atoms (in cysteine) ;
ionic/electrostatic	**and**	charged side chains / cation **and** anion / NH_3^+ **and** COO^- ; ***[2 max]***

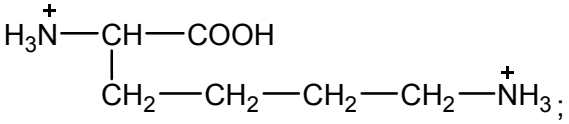
*Award **[1 max]** for two types of interaction **OR** two atoms or groups joined by the interaction.*
*Do not accept "interaction between O and H" **OR** "N and H" alone.*

(b) *At its isoelectric point:*



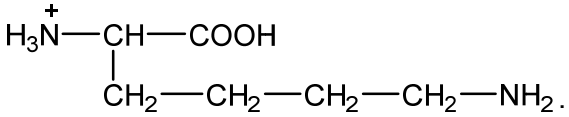
Accept alternate structure where ß–C has NH_2 and NH_3^+ is at the end of carbon chain.

At a pH well below its isoelectric point:



[2]

Accept



Accept alternate structure where ß–C has NH_2 and NH_3^+ is at the end of carbon chain.

7. (a) (mass I_2 reacting with 208.45 g of fatty acid =) $\frac{180 \times 280.45}{100} = 505\,g$;

(moles $I_2 = \frac{505}{253.8} = 2$ hence number of C=C bonds =) 2; ***[2]***

*Award **[1 max]** for correct answer with incorrect working.*

(b) (i) (behenic acid) 41.11 (kJ g^{-1}) **and** (sucrose) 16.40 (kJ g^{-1}); ***[1]***
Ignore negative signs.

(ii) behenic acid contains less oxygen/less oxidised than sucrose; ***[1]***
Accept converse argument for sucrose.

8. (a) *Progesterone:*
(two) carbonyl (groups) **and** alkene;
*Accept "ketone **and** alkenyl/carbon–carbon double bond".*

Estradiol:
(two) hydroxyl (groups) **and** benzene ring/aromatic ring; ***[2]***
Accept "alcohol", "hydroxy" for "hydroxyl", "phenol" for "benzene ring/aromatic ring" but not "hydroxide", "benzene" or "phenyl". Penalize this once only on paper.
*Award **[1 max]** for one different functional group identified for both hormones.*

(b) *Medical use:*
increase/recover muscle mass / induce (delayed) male puberty / treat hormone disorders/sex change;
Do not accept just "gains weight".

Example of abuse:
taken as performance enhancing drugs/PED (in sports to gain unfair advantage) / *OWTTE*; ***[2]***
Do not accept "increase/recover muscle mass" or just "overuse" for abuse.

Option C — Chemistry in industry and technology

9. (a) *Negative electrode (anode):*
cadmium (metal);

Electrolyte:
(aqueous) potassium hydroxide; ***[2]***
Accept "(aqueous) sodium hydroxide" or "(aqueous) lithium hydroxide".

Names required not chemical symbols.

(b) *Negative electrode (cathode):* $Cd(OH)_2(s) + 2e^- \rightarrow Cd(s) + 2OH^-(aq)$
and
Positive electrode (anode): $Ni(OH)_2(s) + OH^-(aq) \rightarrow NiO(OH)(s) + H_2O(l) + e^-$; ***[1]***
Ignore state symbols.
Accept anode half-equation balanced with $2e^-$.
Accept e for e^-.

(c) *Any one for **[1 max]** from*:
both convert chemical energy to electrical energy;
Accept "both are voltaic/galvanic cells".

both involve spontaneous reactions;
both have anode acting as negative electrode / both have cathode acting as positive electrode / both have reduction taking place at positive electrode/cathode / both have oxidation taking place at negative electrode/anode;

*Any two for **[2 max]** from:*
fuel cells work non-stop while rechargeable batteries cannot work while recharging;
fuel cells have longer operating life;
fuel cells need a constant supply of reactants/fuel (producing electrical energy as long as fuel is provided to cell) while rechargeable batteries have stored chemical energy providing power until chemicals are used up;
fuel cells convert energy **and** rechargeable batteries store energy;
fuel cell products must be constantly removed (but not for rechargeable batteries);
fuel cells have inert/inactive electrodes/components while rechargeable have active/non-inert electrodes;
fuel cells run at higher temperatures (compared to rechargeable batteries);
fuel cells require pumps/cooling systems (while rechargeable batteries do not);
chemicals in rechargeable batteries are pollutants / chemicals in fuel cells are not pollutants; ***[3]***
Accept "fuel cells are more expensive (than rechargeable batteries)".

10. (a) in a nanotube all atoms are held together by (strong) covalent bonds;
in graphite there are (weak) intermolecular/London/dispersion/instantaneous induced dipole-induced dipole forces between layers; ***[2]***
Accept "vdW/van der Waals' forces" for "London forces".

(b) hazards/long term effects associated (with small airborne particles) are not known;
nanoparticles have potential to penetrate skin/cell membranes (resulting in unintended effects) / nanoparticles can affect lung tissue/cause breathing problems / workers can be exposed to inhalation of large amounts of nanoparticles / nanoparticles can cause tumours/cancer (by changing genetic material) / nanoparticles can cause heart problems;
human/animal immune system may be defenceless against new nanoscale products;
may not be covered by current toxicology/toxicity regulations (as properties depend on the size of the particle); ***[2 max]***
Accept "nanoparticles can be toxic".

11. (a) *Any two from:*
$2C + O_2 \rightarrow 2CO$;
Allow $C + O_2 \rightarrow CO_2$.

$S + O_2 \rightarrow SO_2$;
$Si + O_2 \rightarrow SiO_2$;
$2Mn + O_2 \rightarrow 2MnO$;
$4P + 5O_2 \rightarrow P_4O_{10}$ / $P_4 + 5O_2 \rightarrow P_4O_{10}$;
Accept P_2O_5 instead of P_4O_{10}.

$CaO + SiO_2 \rightarrow CaSiO_3$;
$6CaO + P_4O_{10} \rightarrow 2Ca_3(PO_4)_2$;
$FeO + CO \rightarrow Fe + CO_2$ / $FeO + C \rightarrow Fe + CO$ / $FeO + Mn \rightarrow Fe + MnO$ /
$2FeO + Si \rightarrow 2Fe + SiO_2$ / $10FeO + P_4 \rightarrow 10Fe + P_4O_{10}$;
$Mn + S \rightarrow MnS$;
$Mn + FeS \rightarrow MnS + Fe$; ***[2 max]***
Ignore state symbols.

(b) high-carbon steel is less malleable/less ductile/harder/more brittle (than low-carbon steel);
high-carbon steel is stronger (than low-carbon steel);
high-carbon steel has a lower melting point (than low-carbon steel);
high carbon steel is less resistant to corrosion (than low-carbon steel); ***[2 max]***
Accept converse points for low-carbon steel.

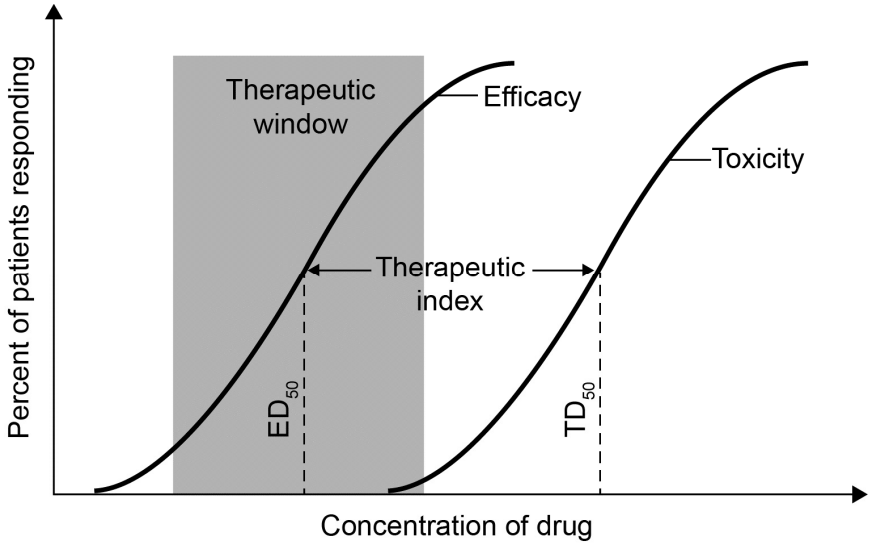
(c) road building/construction / hard core / furnace lining;
landfill (for land reclamation projects);
raw material for sinter plants;
soil conditioner; ***[2 max]***

12. (a) thermotropic are pure substances **and** lyotropic are solutions;
thermotropic exhibit liquid crystal properties in a certain temperature range **and** lyotropic exhibit liquid crystal properties in a certain concentration range; ***[2]***
*Award **[1 max]** for a full description of only one type of liquid-crystal material.*

(b) rod-like/rigid molecules have random positions/are distributed without positional order;
(on average) align in same direction/parallel / have directional order (due to their polarity); ***[2]***

Option D — Medicines and drugs

13. (a) *Therapeutic window:*
range of concentration/dosage over which a drug provides the therapeutic effect without causing adverse effects (to patients) / range of concentration/dosage of drug (able to treat disease successfully) staying within safety limit;
M1 may be scored from a correctly labelled diagram.



Accept "levels for "doses".
Accept "is the relative margin of safety of the drug".

Tolerance:
patient needs to take larger amounts of a drug to have the original effect / *OWTTE*; **[2]**
Do not accept just "body adapts to action of the drug" / OWTTE.
Accept the more precise medical definition of tolerance from the American Academy of Pain Medicine ie, "tolerance is a state of adaptation in which exposure to a drug induces changes that result in a diminution of one or more of the drug's effects over time".

(b) *Advantage:*
convenient/easy to self-administer;

Disadvantage:
drug action is slower / drug may be digested and be ineffective/less potent / the drug (in the tablet) can be deactivated / easy to take too few tablets / easy to take too many tablets (causing an overdose) / hard to swallow (large tablets); **[2]**

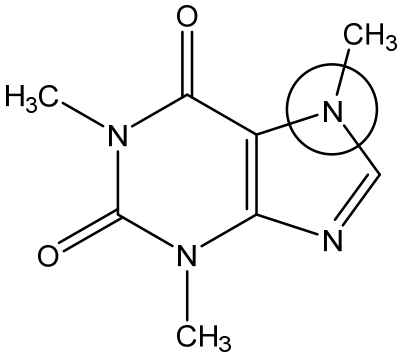
14. (a) hydroxyl; ***[1]***
Accept hydroxy/alcohol/phenol but not hydroxide.

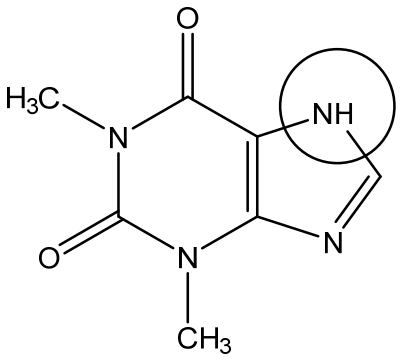
(b) condensation / esterification/acetylation; ***[1]***
Accept "diesterification/diacetylation".

(c) *Diamorphine:*
temporarily binds to/blocks/interferes with receptor sites in the brain / prevents transmission of pain impulses within the CNS/central nervous system;

Mild analgesics:
intercept the pain stimulus at source / blocks/interferes with production of prostaglandins/compounds that cause pain/swelling/fever /
inhibits/blocks/interferes with enzyme at site of pain; ***[2]***
Do not award M2 if prostaglandin is said to be an enzyme.

15. (a)





; ***[1]***

Both circles required for the mark.
Do not accept the imine.

(b) increase (mental) alertness/brain activity;
Do not accept just "increase concentration".

relax air passages;
reduce appetite;
(in large amounts) can cause
restlessness/sleeplessness/insomnia/delusions/hallucinations/fits;
cause palpitations/tremors;
increase blood pressure / constricts blood vessels;
increase heart rate; ***[2 max]***
For (mental) alertness/brain activity, blood pressure and heart rate there must be reference to an increase in these.
Do not accept "increase in sweating".
Do not accept "addiction".

16. (a) alter cell's genetic material;
(change cell membrane so that they) inhibit virus entry/binding to cell;
prevent virus from leaving cell (after reproduction);
become part of DNA of virus / alter virus / block enzyme (polymerase) which builds DNA;
prevent virus from using cell to multiply/reproduce/replicate; ***[2 max]***

(b) mutation of virus/HIV;
virus/HIV metabolism linked to that of host cell / drugs harm host cell as well as virus/HIV;
virus/HIV destroys (helper/T) cells of immune system; ***[1 max]***

(c) leads to resistance/makes antibiotics less effective;
destroys useful/beneficial bacteria;
destroyed bacteria replaced by more harmful bacteria;
resistant bacteria grow/pass on their immunity/mutation to next generation; ***[2 max]***
Do not accept "increased cost of developing antibiotics".

17. (a) *Colour change:*
orange to green;
Accept "yellow to green".

Type of reaction: ***[2]***
redox / oxidation **and** reduction;

(b) *Infrared:*
absorption of C–H / 2850–3100 cm^{-1} measured;
Accept any specific wavenumber within this range.
Accept "absorption of C–O / 1050–1410 cm^{-1} measured".

compare absorption/height/size of peak/intensity to standard/reference;

OR

Fuel cell:
ethanol is oxidised (to CO_2 and H_2O);
current/voltage/potential is proportional to ethanol concentration/level; ***[2]***

Option E — Environmental chemistry

18. (a) (as the concentration/amount of air/oxygen increases) CO emissions decrease;
as CO is oxidized/reacts with oxygen (to form CO_2) / more complete combustion occurs (in engine); ***[2]***

(b) N_2/nitrogen and O_2/oxygen react to produce NO_x/nitrogen oxides;
(as air to fuel ratio increases) amount of air (in engine) increases;
more NO_x/nitrogen oxides produced (as a result);
at very large air to fuel ratios/lean engine temperature in engine drops (less fuel burning);
(reaction between N_2/nitrogen and O_2/oxygen) requires high temperatures; ***[4 max]***

19. (a) nitrogen oxides/NO_x / halons / 1,1,1-trichloroethane / tetrachloromethane/CCl_4; ***[1]***

(b) *Advantage*: do not deplete ozone as they do not contain Cl/C–Cl bonds;
Disadvantage: absorb IR radiation/are greenhouse gases hence contribute to global warming / more expensive to produce; ***[2]***
Do not accept just "HFCs do not contain Cl".

20. (a) *Award **[1]** for any two from:*
requires less energy than extracting metals
preserves ores/raw materials
reduces amounts of waste / waste metals occupy space in landfills
reduces CO_2 emissions that cause global warming
reduces damage to landscape/soil caused by mining
reduces water/air pollution caused by extraction
(alloys can be used) reducing the need for complete purification of the metal
dumping of metals is an environmental hazard; ***[1]***

(b) *Award **[1]** for any two from:*
plastics
glass
paper
textiles
electronics; ***[1]***

21. (a) due to irrigation;
salts (in irrigation water) accumulate in soil as water evaporates;
poor drainage; ***[2 max]***

(b) source of nutrients;
contributes to resilience of soil;
improves structural stability of soil;
improves water-retention;
alters soil's thermal properties;
enhances the ability of soil to buffer pH changes;
forms stable complexes with cations;
contributes to cation-exchange capacity/CEC / ability to hold nutrient ions;
binds to contaminants/heavy metals/pesticides (reducing their effect) / binds to organic (and inorganic) substances; ***[3 max]***
For last marking point there must be a reference to "binding" / OWTTE.

22. (a) *Award **[1]** for any two from:*
food
animal waste
dead animals/plants; ***[1]***
Accept "organic material/sewage".

(b) as oxygen-demanding wastes are high at the farm BOD is high / decay of excess plant growth at farm causes high BOD;
oxygen-demanding wastes broken down downstream from farm decreasing BOD;
oxygen levels decrease as oxygen is used up in the decomposition (of plants);
oxygen levels increase further down as more oxygen dissolves from air/less BOD;
respiration of plants (at night) causes decrease in dissolved oxygen; ***[3 max]***

Option F — Food chemistry

23.

Characteristic	*Nutrient*
Contains an ester group	fats/oils/lipids/triglycerides; *Accept "vitamin C/ascorbic acid".*
Made up of monosaccharides	carbohydrates; *Accept specific correct examples of disaccharides, polysaccharides.*
Essential for healthy bones	calcium (ion) / vitamin D/calciferol; *Accept other nutrients such as "phosphorus", "magnesium" or "protein" but not just vitamins.*

[3]

Accept names, structures of chemical formulas.

24. (a) elaidic acid; ***[1]***
Do not accept molecular formula.

(b) closer packing (of fatty acids) for *trans* isomer / has a greater surface area / greater distortion of electron cloud;
greater London/dispersion/instantaneous induced dipole-induced dipole forces (in *trans* isomer); ***[2]***
Accept "vdW/van der Waals' forces" for "London forces".
Accept greater intermolecular forces (in trans isomer).
Accept converse arguments for cis isomer.

(c) increase levels of LDL cholesterol / decrease levels of HDL cholesterol / less effective as an energy source / accumulates in fatty tissue / difficult to metabolize/digest / are difficult to excrete from the body; ***[1]***
Accept greater risk of cardiovascular disease/atherosclerosis.
*Do **not** accept "increases level of bad cholesterol" or "decreases level of good cholesterol".*

25. (a) (i) bad/disagreeable smell/appearance/texture/taste; ***[1]***

(ii) *Type:*
oxidative;

Explanation:
addition of oxygen/O_2;
to C=C bond/carbon–carbon double bond; ***[3]***

Do not award M2 if M1 is incorrect.

(b) (lower salt content leads to) higher water content;
more microbial spoilage/activity / more reactions involving micro-organisms will take place; ***[2]***

26. (a) carotenoids; ***[1]***
Do not accept "carotenes".
*Accept "Lycopene: carotene **and** zeaxanthin: carotenoid".*

(b) (i) absorb light in the visible region of the spectrum / absorb visible light;
transmit the complementary light; ***[2]***
Accept "reflect" for transmit" but not "emit".

Accept explanations based on pigments having extensive conjugation and needing less energy to excite the electrons so absorption occurs in the visible region of the spectrum / OWTTE.

(ii) *Award **[1]** for any two from:*
temperature
Accept heat/heating.

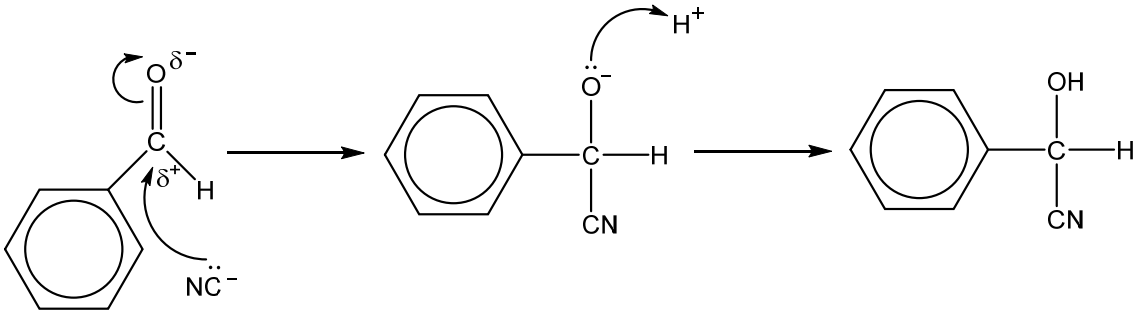
pH
light
effects of oxidative compounds / oxidation
presence of metal ions; ***[1]***

27. (a) (kinetically) stable mixture of one phase in another (largely) immiscible phase; ***[1]***

(b) hydrophobic/non-polar end attracts oils/fats **and** hydrophilic/polar/ionic end attracts water;
lecithin acts as an interface/surface between phases (in the dispersed system); ***[2]***

Option G — Further organic chemistry

28. (a)



curly arrow going from lone pair/negative charge on C in CN^- to carbonyl C **and** curly arrow going from bond in C=O to O;
Do not allow curly arrow originating on N of CN^-.
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]***

(b) (i) CH_3MgBr/CH_3MgI; ***[1]***
Accept "CH_3MgCl".

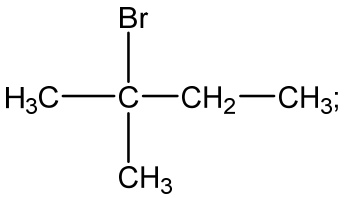
(ii) magnesium/Mg **and** bromomethane/CH_3Br/iodomethane/CH_3I;
Accept "chloromethane/CH_3Cl" for haloalkane.

ether/diethyl ether/ethoxyethane / dry/absence of water; ***[2]***
Accept "non-polar solvent".

(c) *Type of reaction:*
elimination/dehydration;
Reagent:
(conc) phosphoric acid/H_3PO_4;
Accept "(conc) sulfuric acid/H_2SO_4".

Condition:
heat/reflux/180 °C; ***[3]***
Accept any specific value in the range of 150–250 °C.

29. (a)



[1]

Accept either a condensed or full structural formula.

(b) $(CH_3)_2C^+CH_2CH_3$;
more electron-releasing/electron-donating groups in tertiary / inductive effect of alkyl groups pushes electron-density onto positive carbocation in tertiary / *OWTTE*;
tertiary carbocation more stable than secondary carbocation / *OWTTE*; ***[3]***

Do not award marks for reference to Markovnikov's rule without explanation.
Accept structure of secondary carbocation for M1 if consequent converse argument is then conveyed (eg M3: secondary less stable than tertiary).

30. *For the Cl atoms directly attached to the ring:*
C–Cl bonds stronger/less polar owing to delocalization of lone pair on Cl (with the pi electrons in benzene ring) / pi electrons in benzene ring repel OH^-/nucleophile / benzene ring/electron cloud prevents OH^- attacking from opposite direction to C–Cl bond;

For the Cl atoms attached to the $-C_2H_4-$ group:
OH^-/nucleophile attacks the electron-deficient/δ^+C atom attached to Cl; ***[2]***

31. (a) CH_3 is electron-releasing/donating / positive inductive effect;
N is more electron-rich / positive ion/$CH_3NH_3^+$ more stable;
N more likely to accept/attract a proton / $CH_3NH_3^+$ less likely to lose H^+; ***[2 max]***

(b) sodium/potassium/lithium hydroxide; ***[1]***
Accept any other strong base.

32. condensation/addition-elimination;
butanone/$CH_3COCH_2CH_3$; ***[2]***