International Baccalaureate®
Baccalauréat International
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MARKSCHEME

May 2011

CHEMISTRY

Higher Level

Paper 3

19 pages

General Marking Instructions

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. Do not award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified 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 writing ***OWTTE*** (or words to that effect).

8. 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.

9. Only consider units at the end of a calculation.

10. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

11. If a question specifically asks for the name of a substance, do not award a mark for a correct formula, similarly, if the formula is specifically asked for, 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

A1. (a) identification/detection/concentrations of metal/metal ions; ***[1]***

(b) ***X*** *– Name:*
monochromatic light source;
X *– Function:*
produces radiation/light of the same frequency/wavelength as is absorbed by the species (being detected);

Y *– Name:*
atomizer;
Y *– Function:*
converts liquid sample into small droplets / converts metal ions into atoms;

Z *– Name:*
monochromatic detector;
Z *– Function:*
detects radiation/light of the same frequency/wavelength absorbed / converts photons into electric current/signal; ***[6]***

*If **X** and **Z** correct except that "monochromatic" missed both times, penalize once only.*

A2. (a) *Compound:*
CH_3–CH_2–CHO;

Explanation: ***[1 max]***
only this compound would give 3 peaks / *OWTTE*;
only this compound has H–atoms in 3 different chemical environments / *OWTTE*;
only this compound has protons in ratio 3:2:1 in each environment / *OWTTE*
only this compound would give a peak in the 9.4–10 ppm region / *OWTTE*; ***[2]***

(b) triplet;
next to a carbon atom that is attached to two hydrogen atoms; ***[2]***
Apply ECF.
CH_3COCH_3: singlet; no neighbouring H–atoms
CH_2=CH–CH_2OH: correct multiplicity and explanation for any peak.

(c) (i) 1700–1750 cm^{-1} (>C=O); ***[1]***

(ii) 1610–1680 cm^{-1} (>C=C<) / 3200–3600 cm^{-1} (–O–H); ***[1]***

(d) $C_3H_6O^+$ **and** m/z = 58;
$C_2H_5^+$ **and** m/z = 29;
CHO^+ **and** m/z = 29;
CH_3^+ **and** m/z = 15; ***[2 max]***
Penalize missing + sign once only.

A3. (a) silica/silicon dioxide/SiO_2;
alumina/aluminium oxide/Al_2O_3; ***[1 max]***
Accept either of the above.

(b) a spot drawn with its centre 1.4 cm from the start line; ***[1]***
Accept in the range 1.3 to 1.5 cm from the start line.

(c) the relative attraction of the stationary and mobile phases are different of the various components of the mixture / *OWTTE*;

long tube packed with stationary phase;
liquid forced through this under high pressure;
sample injected at start of column;
different components emerge at different times; ***[3 max]***
Any 2 of the above points for the other 2 marks.

A4. (a) structure A pink **and** structure B colourless;
B has a more extended system of delocalization / *OWTTE*; ***[2]***

(b) electron transitions between (split, partially filled) d orbitals;
absorption depends on energy difference between the split d orbitals;
waters replaced by ammonias;
ammonia (ligands) increase the splitting between the d orbitals/larger energy difference;
absorption moves to shorter wavelength/higher frequency/towards blue end of spectrum; ***[3 max]***

Option B — Human biochemistry

B1. (a) both are polymers of glucose;
starch has α-1,4 (and α-1,6 linkages)/α glucose;
cellulose has β-1,4 linkages/β glucose; ***[3]***

(b) absence of cellulase enzyme (in humans); ***[1]***

B2. (a) essential fatty acids/cannot be synthesized in body;
lowers LDL cholesterol level / lowers risk of heart disease / conversion to important molecules; ***[2]***

(b) A: $CH_3(CH_2)_{16}COOH$;
B: $CH_2OHCHOHCH_2OH$; ***[2]***
*Accept **[1 max]** if A and B reversed.*
Accept full structural formula.
Penalize missing H atoms once only.

(c) higher (melting point);
saturated fatty acids / no unsaturation / no C=C bonds; ***[2]***
Accept appropriate reason such as close packing, no kink in molecule, stronger van der Waals' forces.

B3. (a) prevent release of hormones/FSH/LH (from hypothalamus/pituitary gland);
prevent/suppress ovulation/egg release;
prevent attachment of egg to uterus;
prevent sperm from reaching egg/thickens the cervical mucus;
mimics the action of progesterone during pregnancy / fools the reproductive system that the body is pregnant; ***[3 max]***

(b) recovery from injury/surgery/starvation/illness/disease;
increase in muscle mass / enhances performance/strength; ***[2]***

B4. (a) non-competitive (inhibition); ***[1]***

(b) *Absence of inhibitor:*
V_{max} 4.4
K_m 1.7
Accept 1.6–1.8.

Presence of inhibitor:
V_{max} 3.0
K_m 1.7 ***[3]***
Accept 1.6–1.8.

4 values correct, award ***[3]***
3 values correct, award ***[2]***
2 values correct, award ***[1]***
1 value correct, award ***[0]***
Ignore units.

(c) higher the value of K_m, lower the activity of enzyme / lower the value of K_m, higher the activity of enzyme / *OWTTE*; ***[1]***

B5. (a) glucose/$C_6H_{12}O_6$;
$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$; ***[2]***

(b) oxygen/O_2;
$6O_2 + 24H^+ + 24e^- \rightarrow 12H_2O$; ***[2]***
Accept equation divided by 6.
Award ***[2 max]*** *if (a) and (b) are reversed and all 4 marking points are correct.*

(c) ethanol **and** carbon dioxide / C_2H_5OH **and** CO_2; ***[1]***

Option C — Chemistry in industry and technology

C1. (a) (i) a scale of 1–100nm;
careful positioning of individual atoms / ability to control/manipulate at atomic scale / production of material with novel properties; ***[2]***

(ii) health concerns / toxicity / effects on the human immune system / the lack of public involvement in policy discussions; ***[1]***

(b) in the walls carbon atoms only form hexagons;
in the ends the carbon atoms form both hexagons and pentagons; ***[2]***

C2. (a) *Catalytic cracking:*
used to produce moderate length alkanes (for fuels) / lower temperature / lower energy consumption / more control of product;

Thermal cracking:
used to crack very long chain starting material;

Steam cracking:
used to produce low molar mass alkenes (for petrochemicals); ***[3]***

(b) catalyst of $TiCl_4$/$TiCl_3$ **and** $Al(C_2H_5)_3$;
lower temperature **and** lower pressure; ***[2]***
Accept converse argument – higher temperature and pressure required in free-radical polymerization.

(c) make the polymer more flexible;
fits between/increases separation between polymer chains / allow polymer chains to slide past each other more easily / weaken intermolecular attraction; ***[2]***

C3. (a) oxygen blown through/over molten iron;
removes/oxidizes impurities;
alloying materials added (to produce steel required); ***[3]***

(b) *Award **[2 max]** for one of the following pairs:*
annealing – heat to a high temperature **and** slowly cooled;
makes the steel more malleable / more ductile / less brittle;

OR

quenching – heat to a high temperature **and** rapidly cooled;
makes the steel harder / more brittle;

OR

tempering – heat and keep at that temperature for some time;
makes the steel more malleable / more ductile / less brittle; ***[2 max]***

C4. (a) allows cations/Na^+ to pass but prevents anions/Cl^-/OH^- passing; ***[1]***

(b) $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$;
Accept $2H^+(aq) + 2e^- \rightarrow H_2(g)$.

$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$; ***[2]***
Ignore any labelling of anode/cathode.
State symbols are not required.

(c) chlorine – bleach / plastics / water treatment / swimming pool;
sodium hydroxide – pulping wood / industrial alkali / soap manufacture; ***[2]***

C5. doping with/adding small quantities of a Group 3 element (B, Al etc.);
atoms contain less electrons so give "positive holes"/"electron holes" (in the filled band);
these "holes" are able to move and hence allow the silicon to conduct / *OWTTE*; ***[3]***

Option D — Medicines and drugs

D1. (a) amide; *[1]*
Do not accept carbonyl / ketone.

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

(c) anxiety
irritability/restlessness
sleeplessness
increase in urine output/diuretic
trembling/shaking
increased heart rate/tachycardia *[1]*
Award ***[1]*** *for any* ***two*** *symptoms.*

(d) (i) (sympathomimetic drug) mimics the effect of adrenaline / stimulates the sympathetic nervous system; *[1]*

(ii) amphetamine / methamphetamine / speed / ecstasy / cocaine; *[1]*

D2. (a) $Al(OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$ / $Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$; *[1]*
Accept ionic equations.

(b) less effective **and** (magnesium hydroxide) 2/0.2 mol OH^- ions available as compared to (aluminium hydroxide) 3/0.3 mol OH^- ions for neutralization / neutralizes $2H^+$/0.2 mol acid as compared to $3H^+$/0.3 mol acid; *[1]*
Do not accept aluminium hydroxide can neutralize more acid.

(c) *Alginates:*
provide a neutralizing layer on top of the stomach contents / to prevent acid rising up the esophagus / prevents acid reflux/heartburn;

Dimethicone:
as an anti-foaming agent / to prevent flatulence/gas/bloating; *[2]*

D3. (a) viruses do not have cell/cellular structure;
viruses do not have nucleus;
viruses do not have cell wall;
viruses do not have cytoplasm; ***[2 max]***
Accept opposite statements for bacteria.

(b) stops virus replication;
becomes part of DNA of virus / alters virus DNA / blocks polymerase which builds DNA;
changes the cell membrane that inhibits the entry of virus into the cells;
prevents viruses from leaving the cell (after reproducing); ***[2 max]***

(c) HIV mutates (rapidly);
HIV metabolism linked to that of host cell / HIV uses host cell / drugs harm host cell as well as HIV / difficult to target HIV without damaging host cell;
HIV destroys helper cells of the immune system; ***[2 max]***

D4. (a) benzene/aromatic ring;
amine/amino; ***[2]***

(b) secondary/tertiary amine;
Do not accept amine.

amide;
Do not accept carbonyl / ketone.

alkene/C=C double bonds;
indole ring; ***[2 max]***

(c) tetrahydrocannabinol/THC;
relieves extreme pain (in cancer therapy) / relieves nausea (in chemotherapy); ***[2]***

D5. (a) (fluoxetine) amino group **and** reagent HCl/hydrochloric acid/acid/H^+;
(aspirin) carboxylic acid group **and** NaOH/sodium hydroxide/base/OH^-; ***[2]***
*Allow **[1]** for the two correct functional groups.*

(b) increases aqueous/water solubility;
facilitates distribution in the body; ***[2]***

Option E — Environmental chemistry

E1. *Acid 1:*
(HNO_2/HNO_3) high temperature in internal combustion/jet engine;
reaction between N_2 and O_2 at high temperature/lightning;
Accept either of the above for first mark.

$2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$ / $4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$;

Acid 2:
(H_2SO_3/H_2SO_4) from burning of coal/smelting plants/sulfuric acid plants/volcanic activity;
Do not accept combustion of fossil fuels.

$SO_2 + H_2O \rightarrow H_2SO_3$ / $SO_3 + H_2O \rightarrow H_2SO_4$; ***[4 max]***

Allow H_2SO_3/H_2SO_4 to be Acid 1 and HNO_2/HNO_3 to be Acid 2.

E2. (a)

Element	Aerobic decomposition	Anaerobic decomposition
Carbon	CO_2/carbon dioxide	CH_4/methane
Nitrogen	NO_3^-/nitrate	NH_3/R–NH_2/ammonia/amines
Sulfur	SO_4^{2-}/sulfate	H_2S/hydrogen sulfide
Phosphorus	PO_4^{3-}/phosphate	PH_3/phosphine

*8 correct, award **[4]***
*6,7 correct, award **[3]***
*4,5 correct, award **[2]***
*2,3 correct, award **[1]***
*1 correct, award **[0]*** ***[4]***

(b) 162 g of $C_6H_{10}O_5$ requires 192 g of O_2;
0.010 g requires 0.012 g of O_2;

OR

n(organic matter) = $\frac{0.010}{162}$ **and** n(O_2) = $6 \times$ n(organic matter);
$m(O_2) = 6n(\text{organic matter}) \times 32.0 = 0.012\text{g}$; ***[2]***
*Award **[2]** for correct final answer.*

E3. (a) incomplete combustion / air/fuel ratio is low; ***[1]***

(b) $2CO + 2NO \rightarrow 2CO_2 + N_2$ ***[2]***
*Award **[1]** for correct reactants and products and **[1]** for balancing.*
Do not apply ECF.

(c) greenhouse gas/effect; ***[1]***

(d) thermal exhaust reactor **and** lean burn engines; ***[1]***
Do not accept catalytic converter.

E4. (a) reaction II (requires a shorter wavelength);
O_2 has double bond/bond order 2 **and** O_3 intermediate between double and single bonds/bond order of $1\frac{1}{2}$; ***[2]***
Do not accept stronger/weaker bonding without justification for the second marking point.

(b) $NO/NO_x/NO_2$ act as catalysts;
$NO + O_3 \rightarrow NO_2 + O_2$;
$NO_2 + O \rightarrow NO + O_2$; ***[3]***

E5. (a) the amount of exchangeable cations (in clay); ***[1]***

(b) H^+ ions displace exchangeable cations from soil;
reduces nutrients from the soil/leached from soil; ***[2]***

(c) $NO_3^- + 10H^+ + 8e^- \rightarrow NH_4^+ + 3H_2O$;
reduces the availability of nitrogen for plant nutrition / plants take in nitrates but not ammonium salts; ***[2]***

Option F — Food chemistry

F1. (a) *saturated:* Tallow;
mono-unsaturated: Olive oil;
poly-unsaturated: Linseed oil; ***[2 max]***
*3 correct award **[2]**, 2 correct award **[1]**, no marks for just one correct.*

(b) the time that a food can be stored without the flavour/smell/colour/texture/ appearance becoming unacceptable (to the consumer); ***[1]***

(c) fission of C–H bond to produce free radicals;
reaction of alkyl radicals with oxygen to give peroxide radical;
peroxide radical removes H–atom from R–H to give hydroperoxide **and** reform the alkyl radical;
Accept appropriate equations for first three marking points.

aldehydes/ketones; ***[4]***

(d) BHA / BHT / TBHQ / tocopherols;
react with free radicals (to form stable products); ***[2]***
Accept full names of BHA / BHT / TBHQ.

(e) fats with trans configuration across the double bond;
not easily digested / accumulate in body tissue / increase LDL cholesterol levels; ***[2]***

F2. (a) both have extended regions of delocalized bonding/conjugated double bonds; ***[1]***

(b) *An anthocyanin:*
beetroot / red cabbage / blackcurrants / cherries / red grapes / named berries;
Accept any other correct answer, but must have specific names e.g. strawberries instead of berries.

A carotene:
tomato / pumpkin / capsicum / bananas / squash / mango; ***[2]***
Accept any other correct answer but do not accept carrot.

(c) chlorophyll / hemoglobin / heme / myoglobin; ***[1]***

(d) labelling/safety regulations vary (considerably) between countries / a food produced in a country may be considered toxic in another / a toxic compound may not be banned in all countries / *OWTTE*; ***[1]***

F3. (a) a food from an animal or plant in which the DNA/genetic material has been altered by artificial means / *OWTTE*; ***[1]***

(b) *advantages* ***[2 max]***:
quicker growth / reduced maturation time / more harvest per year;
increase resistance to disease/pests / less herbicides/pesticides / improved plant/animal health;
more tolerant of climate/extending its range / lower water consumption;
increase in the yield/productivity/feed efficiency;
improve flavour;
incorporate beneficial substances;
increased shelf life;

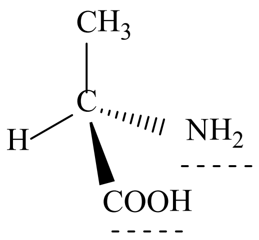
concerns ***[1 max]***:
increase the risk of allergies;
affect the balance of people's diets;
escape of modified genes into the environment;
potential harm to natural ecosystem; ***[3 max]***

F4. (a) carvone;
one isomer tastes of caraway, the other of spearmint;

OR

limonene;
one isomer smells of lemons, the other of oranges; ***[2 max]***

(b) (i)



[1]

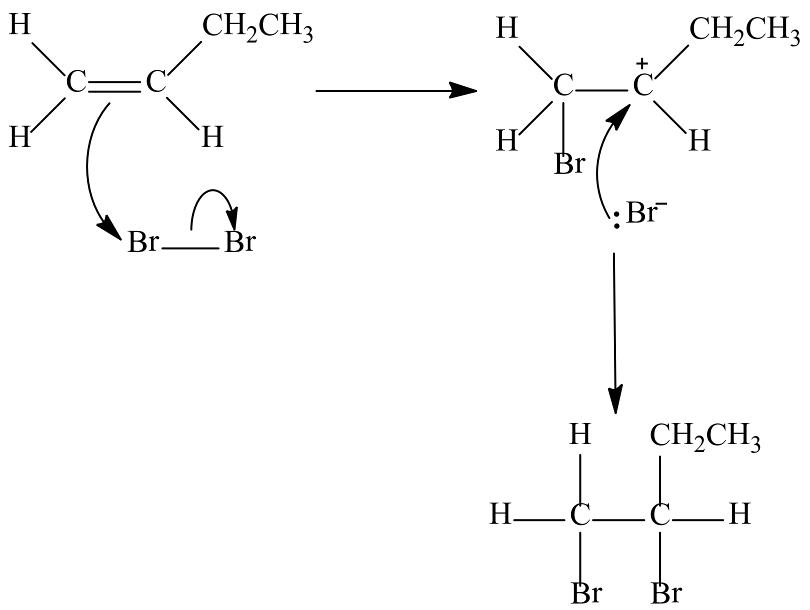
(ii) the R– S– convention; ***[1]***

(iii) not possible to tell; ***[1]***

Option G — Further organic chemistry

G1. (a) $C_2H_5{-}CH(OH){-}CH_3 \rightarrow C_2H_5{-}CH{=}CH_2 + H_2O$;
heat **and** (concentrated) phosphoric acid/H_3PO_4/sulfuric acid/H_2SO_4; ***[2]***

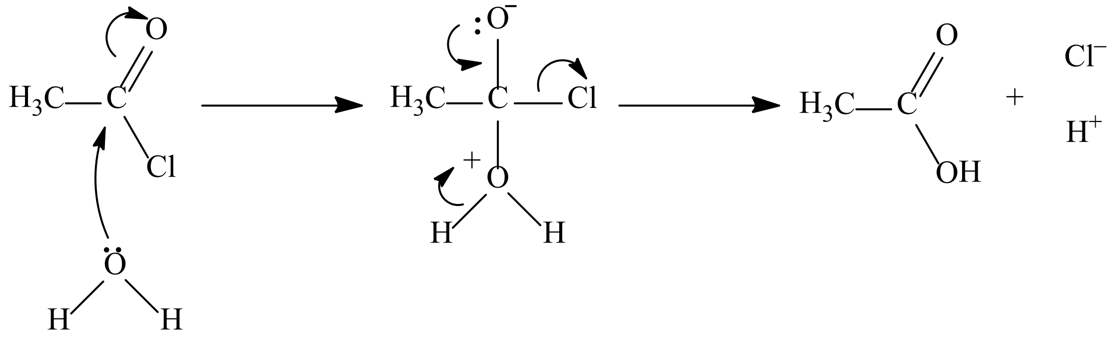
(b)



curly arrow going from C=C to Br of Br_2 **and** curly arrow showing Br atom leaving Br_2 molecule;
representation of carbocation;
curly arrow going from lone pair/negative charge on Br^- to C^+; ***[3]***

(c) butan-1-ol gives higher yield / butan-2-ol gives lower yield;
butan-2-ol will give but-2-ene as well as but-1-ene / butan-1-ol will only give but-1-ene; ***[2]***

G2. (a)



curly arrow going from lone pair on O in H_2O to carbonyl C **and** curly arrow going from C=O bond to O;
Do not allow curly arrow originating on H in H_2O.

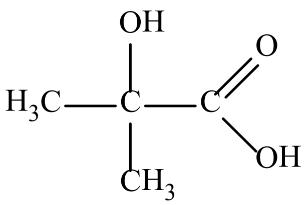
representation of intermediate anion showing negative charge on O **and** + on O of H_2O;
Lone pair on O not required on representation of intermediate.

curly arrow going from lone pair/negative charge on O to C–O to form C=O **and** curly arrow showing Cl leaving **and** curly arrow from H–O bond to O^+;
formation of organic product H_3CCOOH **and** Cl^- and H^+/HCl; ***[4]***

(b) $(CH_3)_2CH$–Mg–Cl;
anhydrous / absence of water / ether solvent; ***[2]***

(c) (i) propanone/CH_3–CO–CH_3 **and** hydrogen cyanide/HCN/cyanide ion/CN^-; ***[1]***

(ii)



/ HO–$C(CH_3)_2$–COOH;

[1]

G3. (a) amine salt;

$[(CH_3)_2NH_2]^+ + OH^- \rightarrow (CH_3)_2NH + H_2O$ /

$[(CH_3)_2NH_2]Br + OH^- \rightarrow (CH_3)_2NH + Br^- + H_2O$ /

$[(CH_3)_2NH_2]^+ + NaOH \rightarrow (CH_3)_2NH + Na^+ + H_2O$ /

$[(CH_3)_2NH_2]Br + NaOH \rightarrow (CH_3)_2NH + NaBr + H_2O$;

[2]

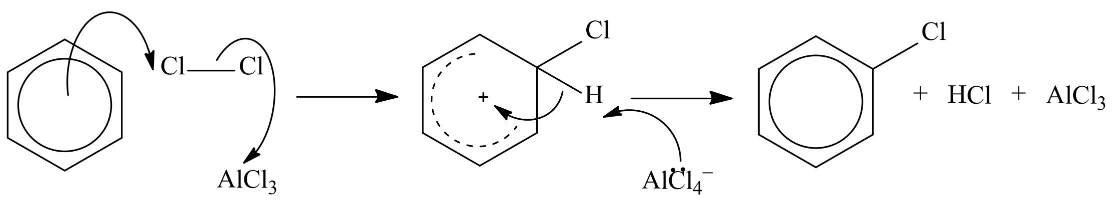
(b) greater / more alkaline;

the inductive/e$^-$ donating effect of the methyl groups reduces the charge on the nitrogen atom of the cation / stabilizes the cation / *OWTTE*;

OR

the inductive/e$^-$ donating effect of the methyl groups increases the negative charge on the nitrogen of the amine so that it attracts H^+ ions more strongly / *OWTTE*; ***[2]***

G4. (a)



curly arrow going from delocalized electrons in benzene to Cl in Cl_2 **and** curly arrow going from Cl–Cl bond to $AlCl_3$;
Allow curly arrow going from delocalized electrons in benzene to Cl^+ for M1.

representation of carbocation with correct formula and positive charge on ring;
curly arrow going from lone pair/negative charge on Cl in $AlCl_4^-$ to H **and** curly arrow going from CH bond to benzene ring;
formation of organic product chlorobenzene **and** HCl **and** $AlCl_3$; ***[4]***
Allow other suitable catalysts such as $FeCl_3$ etc.
Allow mechanism with corresponding Kekulé structures.

(b) methylbenzene more reactive / nitrobenzene less reactive;
methyl group electron donating **and** nitro group electron withdrawing; ***[2]***