**1.** (a) (i) C6H6 + HNO3  C6H5NO2 + H2O **(1)** 1

(ii) (concentrated) sulphuric acid **(1)** 1

(accept H2SO4 but give 0 marks for dilute / (aq))

(iii) NO2+ **(1)** 1

(b) (i) Cl2  2Cl / ½ Cl2  Cl **(1)** 1

(ii) Cl+ C6H5CH3  C6H5CH2 + HCl **(1)**

C6H5CH2 + Cl2  Cl +C6H5CH2Cl **(1)** 2

(iii) C6H5CHCl2 / C6H5CCl3 / C6H5 CHCHC6 H5 /
other correct possible answer **(1)** 1

(c) (i) –CN adding to ethanal correctly showing curly arrow **and** curly arrow from
double bond in C = O

CH3CH(CN) – O–

H+ adding to above ion to form product – ignore curly arrows **(1)** 3

(ii) reaction 1 is nucleophilic **(1)**

reaction 2 is electrophilic **(1)** 2

 **or** accurate idea of why nucleophile / electrophile attacks aldehyde / alkene
including polarity

(d) (i) to satisfy market demand for smaller / unsaturated molecules / alkenes **(1)**

 1

(ii) eg C14H30  C2H4 + C12H26 **(1)** 1

(iii) oxide(s) of S and their effect eg acid rain

not just pollutant or toxic **(1)** 1

[15]

**2.** (a) Step 1:
*Type of reaction* nitration or electrophilic substitution **(1)**

*Reagent(s)* CHNO3 + CH2SO4 **(1)**

Step 3:

*Type of reaction* reduction or amination or hydrogenation **(1)**

*Reagent(s)* HCl/Fe or Sn or Zn or SnCl2 H2/Ni or Cu or Pt or Pd **(1)** 4

(b) HNO3 + 2H2SO4  NO **(1)** + H3O+ + 2HSO **(1)** 2

[6]

**3.** (a) *Reagents* AlCl3 **(1)**

 C6H5CH2COCl or (C6H5CH2CO)2O **(1)**

*Equation for formation of reactive intermediate*
C6H5CH2COCl + AlCl3  C6H5CH2CO+ **(1)** AlCl **(1)**

*Name of mechanism* electrophilic substitution **(1)**

*Mechanism*

 8

(b) *Type of reaction* reduction or hydrogenation **(1)**

 *Reagent(s)* NaBH4 or LiAlH4 H2/Ni or Pt or Pd **(1)**
 or Na/EtOH 2

(c) *Reagents* H2SO4 or H3PO4 or Al2O3 **(1)**

*Name of mechanism* elimination **(1)**

 2

(d) optical 1

(e) *Type of isomerism* geometrical or cis-trans **(1)**

 *Explanation* restricted rotation or
 double bond rigid **(1)** 2

[15]

**4.** (a) (i) 2–methylpropanenitrile **(1)**

(ii) Reagent KCN **(1)**

Conditions alcoholic/aq **(1)**

(iii) *Name of mechanism* nucleophilicsubstitution **(1)**

*Mechanism*

 7

(b) *Reagents* conc HNO3 **(1)** conc H2SO4 **(1)**

*Name of mechanism* electrophilic substitution **(1)**

*Equation* C6H6 + HNO3  C6H5NO2 + H2O

 or C6H6 +  C6H5NO2 + H+ **(1)** 4

(c) electron deficient C or + C in C3H7Br **(1)**

attracts/attacked by nucleophiles **(1)**

electron rich/delocalized electrons in C6H6 **(1)**

repels/not attacked by nucleophiles **(1)** max 3

[14]

**5.** (a) (i) nucleophilic addition **(1)** 1

(ii) 2-hydroxybutanenitrile condone missing hyphen **(1)**

**(1)** 2



(b) (i) CH3CH2CH2Br + KCN  CH3CH2CH2CN + KBr **(1)** 1

 allow C3H7Br allow C4H7N

(ii) nucleophilic substitution / SN2 **(1)** 1

(c) CN– **or** NC– **(1)**

 lone pair of electrons on C atom **(1)** 2

(d) chloromethane or CH3Cl (or Br or I) **(1)**

 AlCl3 / FeCl3 / AlBr3 (as reagent or condition) **(1)**

 anhydrous (ignore reference to temperature) **(1)**

 electrophilic substitution **(1)** 4

[11]

**6.** (a) CH3CH2CH = CH2 + AlCl3 + HCl  CH3CH2HCH3 **(1)**
 + AlCl4– **(1)** 2

(b) electrophilic substitution **(1)** 1

(c) alternative CH3CH2CH2CH2+ or primary **(1)**
less stable or 1 v 2 inductive effects **(1)**
than CH3CH2HCH3 or secondary **(1)** 3

(d) protonation gives CH3CH2HCH3 only **(1)**
or but–2–ene symmetrical 1

(e) CH3CH2CH3 **(1)**

 or Br 1

[8]

**7.** (a) (i) CH3COCl or (CH3CO)2O **(1)**

AlCl3 **(1)**

(ii) reduction or hydrogenation **(1)**

(iii) NaBH4 or LiAlH4 or Na/C2H5OH or H2/Ni **(1)**
 (or H2/Ni)

(iv) elimination or dehydration **(1)**

H2SO4 or H3PO4 or hot Al2O3 **(1)**

 6

(b) (i) poly(phenylethene) or polystyrene **(1)**

(ii) CH3CH2+ or C2H5+ **(1)**
CH2 = CH2 + HCl + AlCl3  CH3CH2+AlCl4– **(1)**

(iii) elimination or dehydrogenation **(1)** 4

[10]

**8.** (a) *Mechanism*

Allow C3H7 if structure shown elsewhere

penalise HCN splitting if wrong

 *Name of* product: 2-hydroxypenta(ne/o)nitrile **(1)** 5
 or 1-cyanobutan-1-ol

(b) *Mechanism*

 *Name of organic product*: methylpropanoate **(1)** 5

(c) (i) ([) CH3CO (])+ **(1)**

(ii) 4

 **Notes**

(abc) extra curly arrows are penalised

(a) be lenient on position of negative sign on : CN– but arrow must come from 1p

(a/b) alone loses M2 but can score M1 for attack on C+, similarly

(a) allow 2-hydroxypentanonitrile or 2-hydroxypenta(ne)nitrile ... pentylnitrile

(b) in M4, allow extra: Cl– attack on H, showing loss of H+

(c) (i) allow formula in an “equation”(balanced or not)
be lenient on the position of the + on the formula

(ii) for M1 the arrow must go to the C or the + on the C
don’t be too harsh about the horseshoe, but + must not be close to the saturated C
M3 must be final step not earlier; allow M3 even if structure (M2) is wrong

[14]

 Organic points

(1) Curly arrows: must show movement of a pair of electrons,
i.e. from bond to atom or from lp to atom / space
e.g.

(2) Structures

penalise sticks (i.e. ) once per paper

Penalise once per paper

 allow CH3– or –CH3 or or CH3
 or H3C–

**9.** (a) *Step 1*

acylation or electrophilic substitution  **(1)**

A1C13  **(1)** CH3CH2COCl or (CH3CH2CO)2O  **(1)**

*Step 2*

reduction or hydrogenation  **(1)**

NaBH4 or hiA1H4 or Na/C2H5OH H2/N1or Pt or Pd  **(1)**

*Step 3*

dehydration or elimination  **(1)**

H2SO4 or H3PO4 or A12O3  **(1)** 7

(b) optical  **(1)** 1

(c) geometrical or cis-trans isomers  **(1)**

due to restricted rotation  **(1)** 2

1. (i)

(ii) electrophilic addition  **(1)**

(iii) C6H5 H CH2CH3  **(1)** C6H5CH2H CH3  **(1)**

both secondary but one is more stable  **(1)** 6

[16]

**10.** (a) dimethylamine 1

(b) nucleophilic substitution 1

 4

(c) quaternary ammonium salt 1

(cationic) surfactant / bactericide / detergent / fabric softener or conditioner/

hair conditioner 1

(d)

*(allow CH3COOH or CH3COO– NH4+)* 2

[10]

**11.** (a) Nucleophilic substitution 1

 4

 M1, M2 and M4 for arrows, M3 for structure of cation

(Allow M2 alone first, i.e. SN1 formation of carbocation)

(Penalise M4 if Br– used to remove H+)

(b) Step 1 CH3CH2CH2CN 1
 CH3CH2CH2Br + KCN  CH3CH2CH2CN + KBr balanced 1
 (or CN–) (or Br–)
 (*not HCN*) 1

Step 2 CH3CH2CH2CN + 2H2  CH3CH2CH2CH2NH2 1
 (or 4[H])

(c) (i) Lone pair (on N) (in correct context) 1
R group increases electron density / donates electrons /pushes
electrons / has positive inductive effect 1

(ii) Any strong acid (but not concentrated)
or any amine salt or ammonium salt of a strong acid 1

(d) CH3CH2N(CH3)2 1

[12]

**12.** (a) (i) chloromethane, anyhalogenomethane (correct formula accepted) **(1)**

aluminium chloride / Fe / FeCl3 /BF3 **(1)**

anhydrous **(1)** 3

(ii) electrophilic **(1)**

substitution **(1)** 2

(b)

and other correct products 3

penalise C6H5 once only

(c) (i) reduction / redox **(1)** 1

(ii) 2

cation only, give 2

only phenylamine, give

salt correct with charges omitted, give 2

(d) (i)

**(1)**

reduction / redox / hydrogenation / addition **not** electrophilic addition **(1)** 2

(ii)

oxidation /redox **(1)** 2

(iii)

 **(1)**

addition **not** electrophilic addition **(1)** 2

[17]

**13.** (a) CHNO3 + CH2SO4  **(1)**

HNO3 + 2H2SO4  NO **(1)** + H3O+ + 2HSO **(1)**

electrophilic substitution  **(1)**

 7

(b) reduction or hydrogenation  **(1)**

HC1/Fe or Sn or Zn or Sn Cl2 H2/Ni or Pt or Pd or Cu  **(1)** 2

(c) C6H5NH2 + CH3 COCl  **(1)**  C6H5NHCOCH3 + HCl  **(1)**

or C6H5NH2 + (CH3CO)2O  C6H5NH COCH3 + CH3 COOH

nucleophilic addition-elemination  **(1)**

 7

[16]

**14.** (a) lone pair on N  **(1)**

donated to H+ or proton acceptor  **(1)** 2

(b) lone pair on N less available  **(1)**

due to delocatisation  **(1)** 2

(c) (i) nucleophilic substitution  **(1)**

(ii) (CH3)2 NH  **(1)**

(CH3)3 N  **(1)**

(CH3)4 N+ Br–  **(1)**

(iii) quaternary ammonium salt  **(1)** 5

[9]

**15.** (a) (i) CH3CN + 4[H] (or 2H2)  CH3CH2NH2 **(1)**

(ii) LiAlH4 or Na/C2H5OH (or H2/Ni) **(1)** 2

(b) (nucleophilic) substitution or alkylation **(1)**

 *Product 1* *Product 2* *Product 3*

(C2H5)2NH (C2H5)3N (C2H5)4N+Br–

 **(1)** **(1)** **(1)** 4

(c) 3

(d) lone pair on N less available
or electron density on N decreased **(1)**
due to delocalisation **(1)** 2

(e) electron withdrawal by O or CO
or delocalisation by CO **(1)** reduces electron
density on N or makes N lone pair less available **(1)** 2

(f) 2C2H5NH2 + CH3COCl **(1)**  CH3CONHC2H5 + C2H5NH3+Cl– **(1)**
(nucleopholic) addition – elimination **(1)**

 7

[20]

**16.** (a) (i) H+ or proton acceptor **(1)**CH3NH2 + H2O () CH3+NH3 (+) OH– **(1)**

(ii) CH3NH3Cl or HCl **(1)**

Or any ammonium compound or strong acid
name or formula

(iii) extra OH– reacts with
or reaction / equilibrium moves to left
or ratio salt / base remains almost constant **(1)**

Any 2

 5

(b) lone pair (on N accepts H+) **(1)**CH3 increases electron density (on N)
 donates / pushes electrons
 has positive inductive effect **(1)** 2

(c) nucleophilic substitution **(1)
 (1)** 2

[9]

**17.** (a) (i) *Equation* C6H5CH2Br + 2NH3  C6H5CH2NH2 + NH4Br **(1)**
 **(1)**
*Type of reaction* nucleophilic subsn or alkylation  **(1)**
*Explanation*  further substitution occurs  **(1)**
 o give a mixture of products  **(1)**

(ii) reduction or hydrogenation  **(1)**
C6H5CN + 4[H]  C6H5CH2NH2  **(1)**
 or 2H2
Na/C2H5OH or LiAlH4 or H2/Ni  **(1)**
only one product formed  **(1)**
or avoids further substitution 9

(b) *Weaker* base phenylamine  **(1)**
*Explanation* lone pair on N less available or electron density on
 N lowered  **(1)**
 due to delocalisation or overlap  **(1)** 3

[12]

**18.** (a) (i) cHNO3 + cH2SO4 **(1)**
HNO3 + 2H2SO4  NO2+ **(1)** + H3O+ + 2HSO4– **(1)**

(ii) electrophilic substitution **(1)**

 7

(b) *Type of reaction* reduction **(1)** not hydrogenation

*Reagent(s)* NaBH4 or Na/C2H5OH **(1)** not LiAlH4
 not H2/Ni 2

(c) *Reagent* CH3COCl or (CH3CO)2O **(1)**
*Name of mechanism* (nucleophilic addition–elimination **(1)**

*Mechanism*

 6

(d) *Type of reaction* reduction or hydrogenation **(1)**
*Reagent(s)* HCl/Fe or Sn or Zn H2/Ni or Pt or Pd **(1)**
 or SnCl2 or Ni/H2

*not LiAlH4* 2

(e) optical **(1)** 1

[18]

**19.** (a) (i) lone pair on N **(1)**

(ii) inductive effect of CH3 or electron donation **(1)**
increases electron density on N
or lone pair more available **(1)**

(iii) electron density on N decreased
or lone pair less available **(1)**
due to delocalisation **(1)** 5

(b) (i) *Equation* CH3CH2CN + 2H2  CH3CH2CH2NH2 **(1)**
*Catalyst* Ni **(1)**

(ii) nucleophilic substitution **(1)**

(iii) further reaction can occur **(1)**
between propylamine and 1-bromopropane **(1)** 5

(c) CH3CH2CH2NHCOCH3 **(1)** 1

(d) *Type of product* quaternary ammonium salt or chloride **(1)**
*Structural formula*

CH3(CH2)11N+(CH3)3 **(1)**
 Cl– **(1)** 3

[14]

**20.** (a) Lone pair on nitrogen **(1)** less available or
electron density lowered **(1)** due to delocalisation or
resonance or mesomerism or part of x bond **(1)** 3

(b) *Equation*  C6H11Br + 2NH3  C6H11NH2 + NH4Br **(1)**

*Name of mechanism* nucleophilic substitution **(1)**

*Mechanism*

 6

(c) (i) NaCN or KCN **(1)**

(ii) *Reagent(s)* Na/C2H5OH or LiAlH4 or H2/Ni **(1)**

*Type of reaction* reduction or hydrogenation **(1)**

 *Equation* C6H11CN + 4[H]  C6H11CH2NH2 **(1)**
 or 2H2 if hydrogenation 4

(d) *Equation*  2RNH2 + CH3COCl  RNHCOCH3 **(1)** + RNH3Cl **(1)**

*Name of mechanism* (nucleophilic) addition-elimination **(1)**

*Mechanism*

 7

[20]

**21.** (a) (i) suitable graphical formula for ethanoic anhydride **(1)** 1

(ii) (acid) anhydride **(1)** 1

(b) (i) **F =** ethylamine / aminoethane **(1)** 1

(ii) reduction **or** hydrogenation **or** addition (ignore reference
to mechanism) **(1)**

 1

(c) CH3COCl + CH3CH2NH2  CH3CONHCH2CH3 + HCl

 CH3CONHCH2CH3 **(1)**

 balanced **(1)** 2

[6]

**22.** (a) Lone pair on N or electron density on N **(1)**
more available or electron density increased **(1)**
electron donation or inductive effect **(1)** 3

(b) *Reagent(s)* LiAlH4 or Na/EtOH or H2/Ni **(1)**

*Type of reaction* reduction or hydrogenation **(1)**

*Equation* CH3CN + 4[H] or 2H2  CH3CH2NH2 **(1)** 3

(c) (C2H5)4N+Br– **(1)**

quaternary ammonium salt **(1)**

 cationic surfactant **(1)**
or fabric softener 3

(d) *Name of mechanism* addition-elimination **(1)**

*Mechanism*

 5



(e) C2H5NH2 + (CH3CO)2O  C2H5NHCOCH3 + CH3COOH **(1)**
or 2C2H5NH2 + (CH3CO)2O  C2H5NHCOCH3 + CH3COO–H3C2H5 1

[15]

**23.** (a) (nucleophilic) addition-elimination; 1

(M3 for structure)
(M4 for 3 arrows and lone pair)
(M2 not allowed independent of M1, but allow M1 for correct attack
on C+ if M2 show as independent first.)
(+on C of C=O loses M2 but ignore + if correct)
(Cl– removing Ft loses M4)

 5

(If MS lost above for wrong C chain, do not penalise same error again here)

(b) CH3CH2COCl + AlCl3  [CH3CH2CO]+ + AlCl4–; 1

(penalise wrong alkyl group once at first error)

(position of + on electrophile can be on O or C or outside [ ]) (penalise wrong curly arrow in the equation or lone pair on AlCl3)

|  |  |
| --- | --- |
| *(M1 arrow from within hexagon to C or to + on C)**(don’t penalise position of + on C of RCO+)* | (horseshoe must not extend beyond C2 to C6 *but can be smaller)**(+ not too close to C1)**(penalise M2 if CH*3 *chain wrong again but allow M1 and M3)**(M3 arrow into hexagon unless Kekule)**(allow M3 arrow independent of M2 structure)* |

 3

 1

(or can be gained in mechanism);

(c) M1 CH3CH2COCl + H2O → CH3CH2COOH + HCl 1 1
*(penalise wrong alkyl group once at first error)*

 M2 Mr of CH3CH2COCl = 92.5 1 1
*(if Mr wrong, penalise M2 only)*

 M3 moles of CH3CH2COCl = 1.48/92.5 = 0.016 1 1

 M4 moles NaOH = 2 × 0.016 = 0.032 1 1
*(allow for* × *2 conseq to wrong no of moles)*

 M5 volume of NaOH = 0.032/0.42 = 0.0762 dm3 or 76.2 cm3 1
*(with correct units)
(if* ×*2 missed in M4 lose M5 also)* 1

[16]

**24.** (a) CH3COCl + AlCl3  CH3O + AlCl 1

 equation 1

 penalise wrong alkyl group once at first error
position of + on electrophile can be on O or C or outside [ ]
penalise wrong curly arrow in the equation or lone pair on AlCl3 else ignore

 Electrophilic\_substitution 1

NOT F/C acylation

horseshoe must not extend beyond C2 to C6 but can be smaller

+ not too close to C1

M3 arrow into hexagon unless Kekule

allow M3 arrow independent of M2 structure

 M1 arrow from within hexagon to C or to + on C
+ must be on C of 3

(b) Nucleophilic\_addition NOT reduction 1

 4

M2 not allowed independent, but can allow M1 for attack of H– on C+ formed

 1–phenylethan(–1–)ol or (1–hydroxyethyl)benzene 1

(c) dehydration or elimination 1
(conc) H2SO4 or (conc) H3PO4 1

allow dilute and Al2O3

Do not allow iron oxides

[14]

**25.** (a) ethyl benzene 1

chloroethane or bromoethane *(or ethene and hydrogen chloride/bromide)* 1

aluminium chloride/bromide or iron(III) chloride /bromide or iron +

chorine/bromine 1

CH3CH2Cl + AlCl3 → CH3CH2+ + AlCl4– 1

electrophilic substitution 1

 3

(b) 1

CH3CH2COCl / propanoyl chloride or (CH3CH2CO)2O / propanoic anhydride 1

NaBH4 or LiAlH4 or H2/Ni (*not Sn/Fe with HCl*) 1

[11]

**26.** **X** is CH3CN or ethanenitrile or ethanonitrile or methyl cyanide or 1
cyanomethane or ethyl nitrile or methanecarbonitrile

**Not** ethanitrile
but contradiciton of name and structure lose marks

 **Y** is CH3CH2NH2 or ethylamine or aminoethane or ethanamine 1

 Step 1: reagent KCN not HCN/HCl 1
 condition (aq)/alcohol - only allow condition if reagent
 correct or incomplete 1

 Step 2: reagent H2 LiAlH4 Na Zn/Fe/Sn Not NaBH4 1
 condition Ni/Pt/Pd ether ethanol HCl 1

 **Z** is an amine or aminoalkane or named amine even if incorrect name for **Z** 1
 secondary (only award if amine correct)

 (Br–)+ can be on N or outside brackets as shown 1

 nucleophilic substitution 1

[9]

**27.** (a) Cyclohexane evolves 120 kJ mol–1
 (expect triene to evole) 360 kJ mol–1 **(1)** or 3 × 120
360 – 208 = 152 kJ **(1)** NOT 1504

152 can score first 2

QofL: benzene lower in energy / more (stated) stable **(1)**
Not award if mentions energy required for bond breaking

 due to delocalisation **(1)** or explained

(b) (i) phenylamine weaker **(1)**

if wrong no marks

 lone pair on N (less available) **(1)**
delocalised into ring **(1)** or “explained” 3

(ii) addition – elimination **(1)**

structure **(1)** M3
3 arrows **(1)** M4

N-phenyl ethanamide **(1)** 6

(iii) conc HNO3 **(1)**
conc H2SO4 **(1)**
HNO3 + 2H2SO4  O2 + H3O+ + 2HSO4– **(1)**

 6

(iv) peptide / amide **(1)**
NaOH (aq) **(1)** 2

HCl conc or dil or neither
H2SO4 dil NOT conc

NOT just H2O

**Notes**

(a)  360 or 3 × 120 or in words **(1)**;
 152 NOT 150 **(1)**; (152 can get first two marks)
 **Q of L** benzene more stable but not award if H values used to say
that more energy is required by benzene for hydrogenation compared with
the triene or if benzene is only compared with cyclohexene **(1)**;
 delocalisation or explained **(1)**

(b) (ii) or N-phenylacetamide or acetanilide
mechanism: if shown as substitution can only gain M1
if CH3CO+ formed can only gain M1
lose M4 if Cl– removes H+
be lenient with structures for M1 and M2 but must be correct for M3
 alone loses M2

(iii) **No marks for name of mechanism in this part**
if conc missing can score one for both acids (or in equation)
allow two equations
allow HNO3 + H2SO4  NO2+ + HSO4– + H2O
ignore side chain in mechanism even if wrong
arrow for M1 must come from niside hexagon
arrow to NO2+ must go to N but be lenient over position of +
+ must not be too near “tetrahedral” Carbon
horseshoe from carbons 2-6 but don’t be too harsh

(iv) reagent allow NaOH
HCl conc or dil or neither
H2SO4 dil or neither but not conc
not just H2O

[21]