

AQA A-LEVEL CHEMISTRY • 7405

CHEMISTRY



EXAM QUESTION PACK

3.3.11 AMINES

SCORE

/121

PERCENTAGE

%

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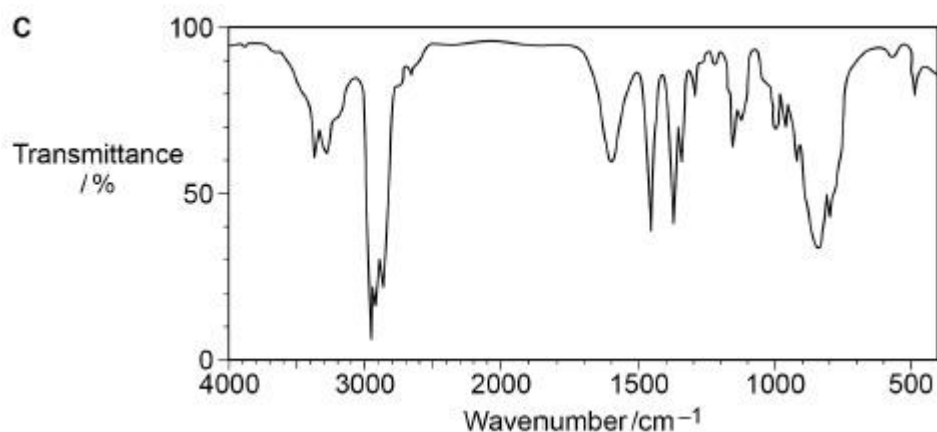
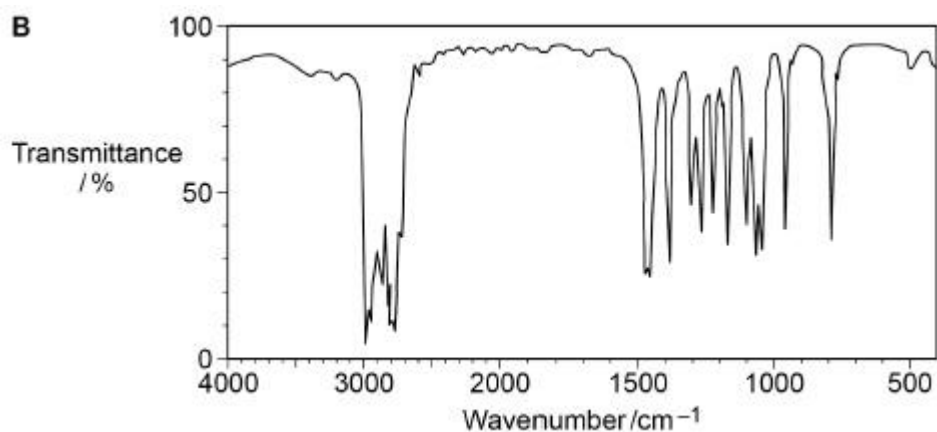
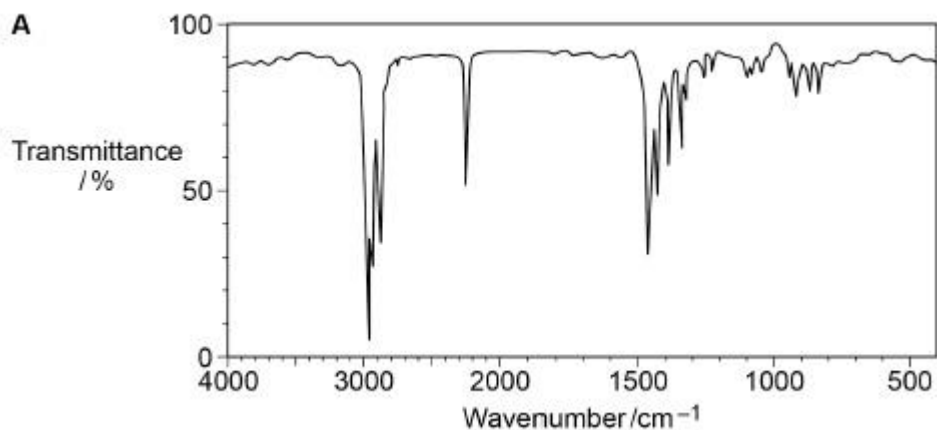
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Q1.

This question is about amines.

- (a) The infrared spectra **A**, **B** and **C** are those of a primary amine, a tertiary amine and a nitrile, but not necessarily in that order.



Give the letter of each compound in the correct box.

primary amine	tertiary amine	nitrile

(1)

- (b) There are **three** secondary amines that contain four carbon atoms per molecule.

Draw the skeletal formulas of these **three** secondary amines.

(2)

- (c) Primary amines can be prepared by the reaction of halogenoalkanes with ammonia or by the reduction of nitriles.

Justify the statement that it is better to prepare primary amines from nitriles rather than from halogenoalkanes.

(2)

- (d) Draw the structure of a primary amine with four carbon atoms that **cannot** be formed from a nitrile.

(1)

- (e) A student dissolves a few drops of propylamine in 1 cm³ of water in a test tube.

Give an equation for the reaction that occurs.

Describe what is observed when Universal Indicator is added to this solution.

Equation _____

Observation _____

(2)

- (f) Phenylamine can be prepared by a process involving the reduction of nitrobenzene using tin and an excess of hydrochloric acid.

Give an equation for the reduction of nitrobenzene to form phenylamine. Use [H] to represent the reducing agent.

Explain why an aqueous solution is obtained in this reduction even though phenylamine is insoluble in water.

Equation _____

Explanation _____

(2)

(Total 10 marks)

Q2.

Aqueous solutions of ammonia, ethylamine and phenylamine are prepared. Each solution has the same concentration.

Which is the correct order for the pH values of these solutions?

A ammonia > ethylamine > phenylamine

☐

B ammonia > phenylamine > ethylamine

☐

C ethylamine > ammonia > phenylamine

☐

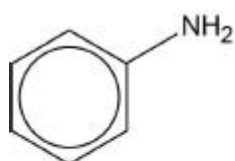
D ethylamine > phenylamine > ammonia

☐

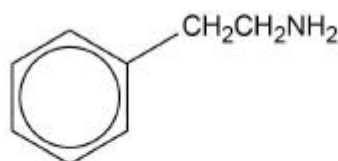
(Total 1 mark)

Q3.

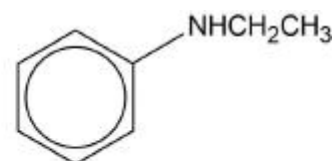
This question is about the three amines, **E**, **F** and **G**.



E



F



G

- (a) Amines **E**, **F** and **G** are weak bases.

Explain the difference in base strength of the three amines and give the order of increasing base strength.

(6)

- (b) Amine **F** can be prepared in a three-step synthesis starting from methylbenzene.

Suggest the structures of the two intermediate compounds.

For each step, give reagents and conditions only. Equations and mechanisms are **not** required.

(5)

(Total 11 marks)

Q4.

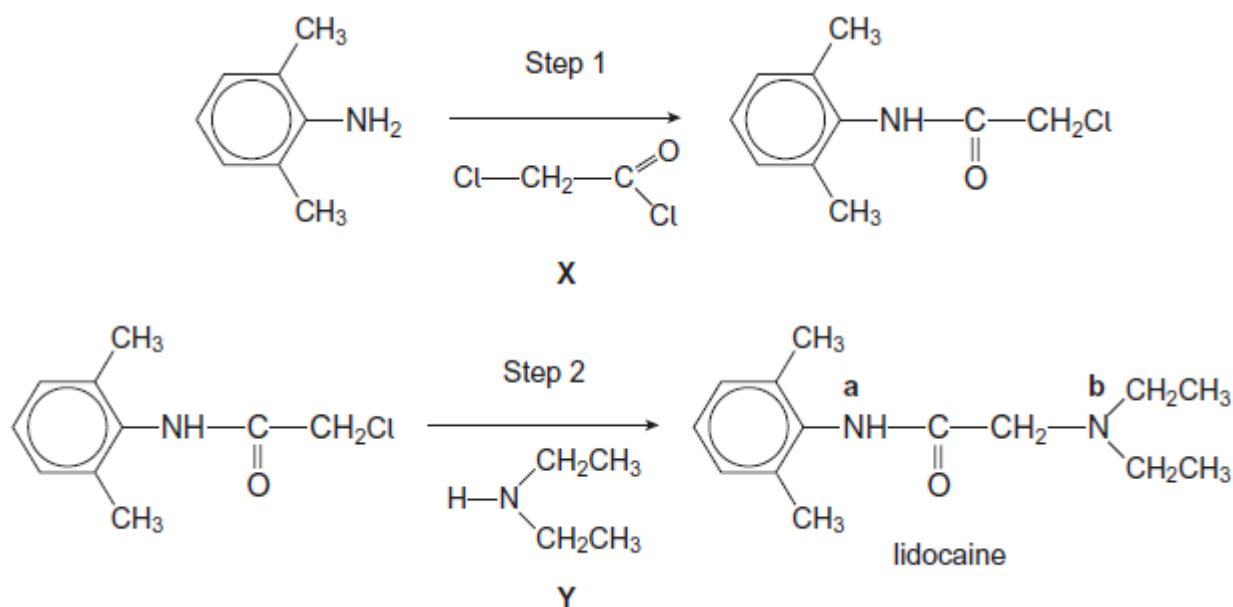
Which compound is the strongest base?

- | | | |
|----------|-------------------|-----------------------|
| A | Ammonia | ☐ |
| B | Ammonium chloride | ☐ |
| C | Methylamine | ☐ |



Q5.

Lidocaine is a local anaesthetic used in dentistry and in minor surgical operations. The synthesis of lidocaine in 2 steps from 2,6-dimethylphenylamine is shown.



- (a) (i) Give the IUPAC name of reagent **X** in Step 1.

(1)

- (ii) Outline a mechanism for Step 1.
In your answer, use RNH_2 to represent 2,6-dimethylphenylamine.

(4)

- (b) Name the mechanism for Step 2.

(1)

- (c) Which of these is the total number of peaks in the ^{13}C n.m.r spectrum of lidocaine?

Tick (✓) one box.

8 ☐

9 ☐

11 ☐

12 ☐

(1)

- (d) Calculate the percentage by mass of hydrogen in a molecule of lidocaine.

(2)

- (e) Give the name, including the classification, of the functional group that contains the nitrogen atom labelled **b**.

(1)

- (f) Lidocaine is used medically as the salt lidocaine hydrochloride.

- (i) Suggest which one of the nitrogen atoms labelled **a** or **b** is protonated in lidocaine hydrochloride. Explain your answer.

Nitrogen atom protonated _____

Explanation _____

(3)

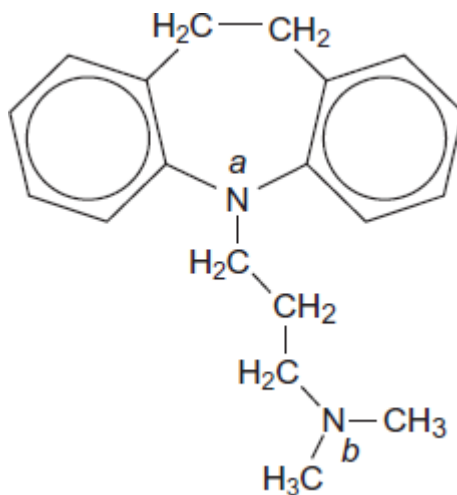
- (ii) Suggest why lidocaine hydrochloride is used medically in preference to lidocaine.
Explain your answer.

(2)

(Total 15 marks)

Q6.

Imipramine has been prescribed as an antidepressant. The structure of imipramine is shown below.



- (a) The medicine is usually supplied as a salt. The salt is formed when one mole of imipramine reacts with one mole of hydrochloric acid.

Suggest why the nitrogen atom labelled *b* is more likely to be protonated than the nitrogen atom labelled *a* when the salt is formed.

(3)

- (b) Deduce the molecular formula of imipramine and give the number of peaks in its ^{13}C n.m.r. spectrum.

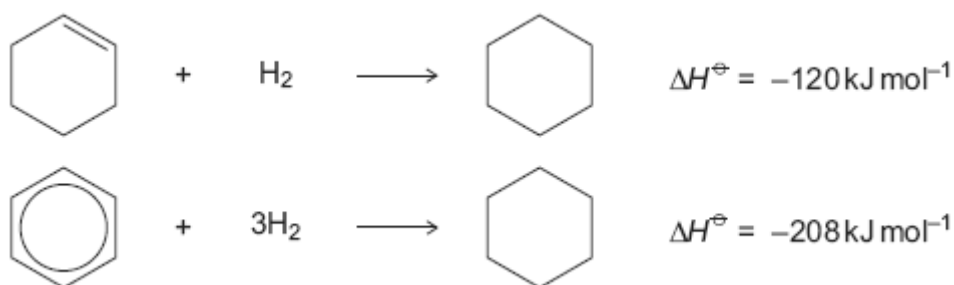
(2)

(Total 5 marks)

Q7.

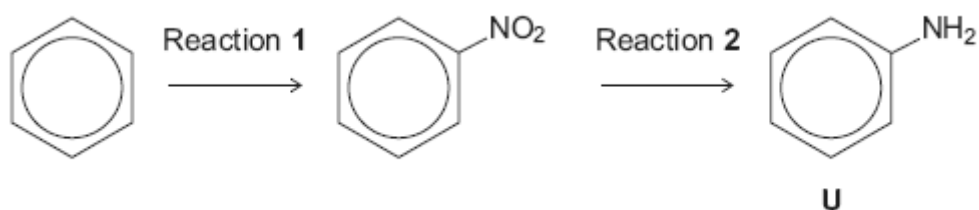
The hydrocarbons benzene and cyclohexene are both unsaturated compounds. Benzene normally undergoes substitution reactions, but cyclohexene normally undergoes addition reactions.

- (a) The molecule cyclohexatriene does not exist and is described as hypothetical. Use the following data to state and explain the stability of benzene compared with the hypothetical cyclohexatriene.



(4)

- (b) Benzene can be converted into amine **U** by the two-step synthesis shown below.



The mechanism of Reaction 1 involves attack by an electrophile.

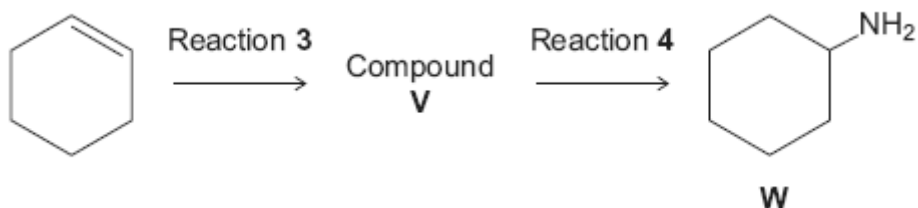
Give the reagents used to produce the electrophile needed in Reaction 1.

Write an equation showing the formation of this electrophile.

Outline a mechanism for the reaction of this electrophile with benzene.

(6)

- (c) Cyclohexene can be converted into amine **W** by the two-step synthesis shown below.



Suggest an identity for compound **V**.

For Reaction **3**, give the reagent used and name the mechanism.

For Reaction **4**, give the reagent and condition used and name the mechanism.

Equations and mechanisms with curly arrows are **not** required.

(6)

- (d) Explain why amine **U** is a weaker base than amine **W**.

(3)

(Total 19 marks)

Q8.

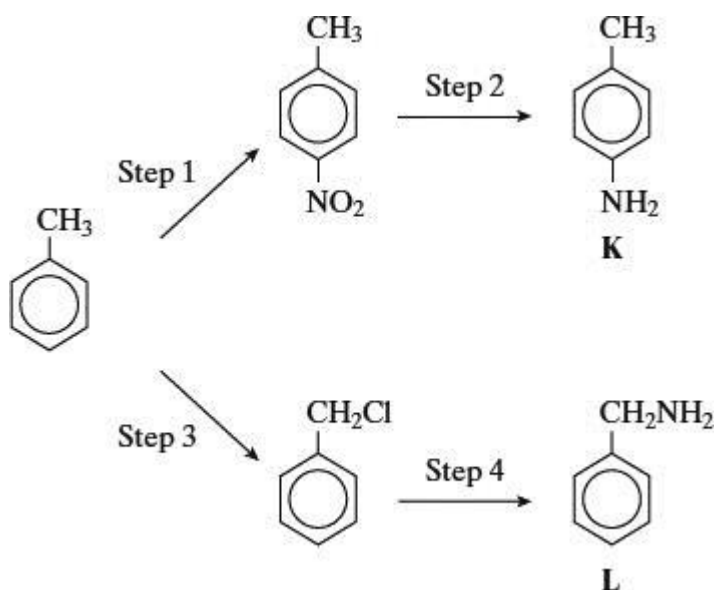
Which one of the following reactions does **not** involve donation of an electron pair?

- A** $\text{H}^+ + \text{CH}_3\text{NH}_2 \rightarrow \text{CH}_3\text{NH}_3^+$
- B** $\text{AlCl}_3 + \text{Cl}^- \rightarrow \text{AlCl}_4^-$
- C** $\text{CH}_3\text{Cl} + \text{CN}^- \rightarrow \text{CH}_3\text{CN} + \text{Cl}^-$
- D** $\frac{1}{2}\text{Cl}_2 + \text{I}^- \rightarrow \text{Cl}^- + \frac{1}{2}\text{I}_2$

(Total 1 mark)

Q9.

The following reaction scheme shows the formation of two amines, **K** and **L**, from methylbenzene.



- (a) (i) Give the reagents needed to carry out Step 1. Write an equation for the formation from these reagents of the inorganic species which reacts with methylbenzene.

Reagents _____

Equation _____

- (ii) Name and outline a mechanism for the reaction between this inorganic species and methylbenzene.

Name of mechanism _____

Mechanism

(7)

- (b) Give a suitable reagent or combination of reagents for Step 2.

(1)

- (c) (i) Give the reagent for Step 4 and state a condition to ensure that the primary amine is the major product.

Reagent _____

Condition _____

- (ii) Name and outline a mechanism for Step 4.

Name of mechanism _____

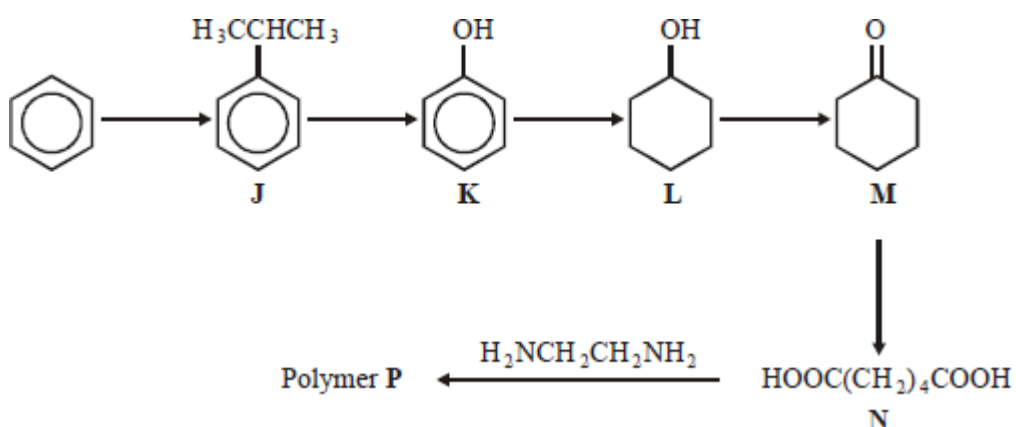
Mechanism

(7)

(Total 15 marks)

Q10.

This question is about the following reaction scheme which shows the preparation of polymer **P**.



Polymer **P** is formed in a two-step reaction from **N**. The first stage is a neutralisation reaction. The volume, in cm^3 , of a 0.20 mol dm^{-3} solution of $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ required to neutralise $6.8 \times 10^{-3} \text{ mol}$ of the acid **N** is

A 17

- B** 34
C 68
D 136

(Total 1 mark)

Q11.

- (a) Name and outline a mechanism for the formation of butylamine, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$, by the reaction of ammonia with 1-bromobutane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$.

Name of mechanism _____

Mechanism

(5)

- (b) Butylamine can also be prepared in a two-step synthesis starting from 1-bromopropane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$. Write an equation for each of the two steps in this synthesis.

Step 1

Step 2

(3)

- (c) (i) Explain why butylamine is a stronger base than ammonia.

- (ii) Identify a substance that could be added to aqueous butylamine to produce a basic buffer solution.

(3)

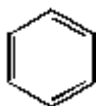
- (d) Draw the structure of a tertiary amine which is an isomer of butylamine.

(1)

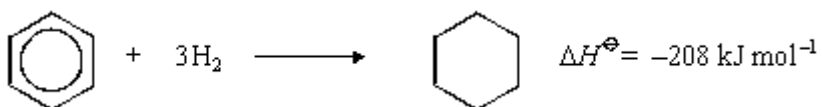
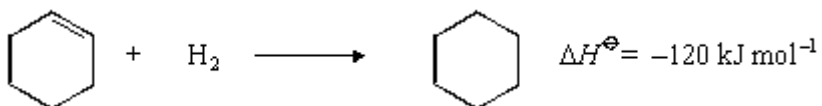
(Total 12 marks)

Q12.

- (a) Use the following data to show the stability of benzene relative to the hypothetical cyclohexa-1,3,5-triene.

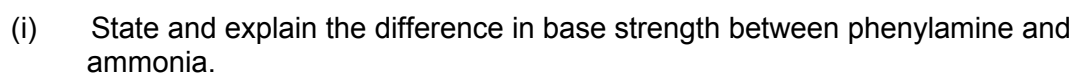


Give a reason for this difference in stability.



(4)

- (b) Consider the following reaction sequence which starts from phenylamine.



(3)

- (6)**

(6)

-
-
-
-

(2)

(Total 21 marks)

Q13.

(5)

- (b) Explain why methylamine is a stronger base than ammonia.

(2)

- (c) A cation is formed when methylamine reacts with a large excess of bromoethane. Name the mechanism involved in the reaction and draw the structure of the cation formed.

Name of mechanism _____

Structure

(2)

(Total 9 marks)

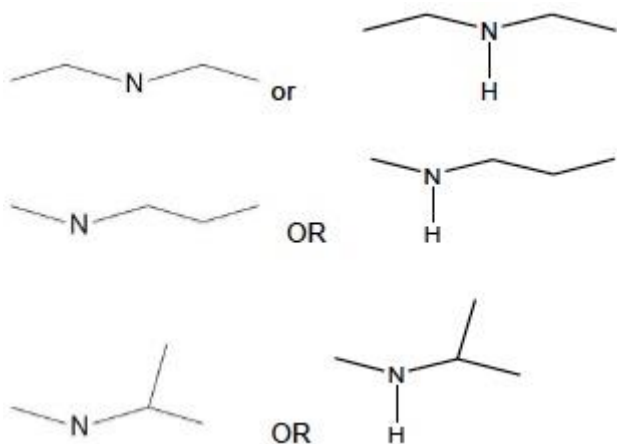
Mark schemes

Q1.

- (a) C B A this order only

1

- (b) Any three from

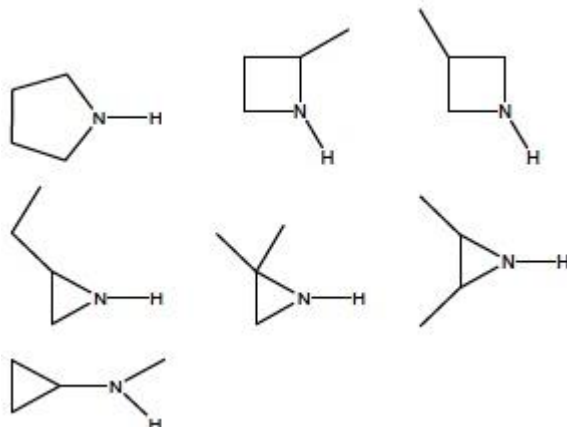


Must be skeletal – allow with or without H on N

All 3 correct score 2 (or one if not skeletal)

Any two correct score 1 (or zero if not skeletal)

Allow cyclic 1° amines but NOT amines also containing other functional groups



2

- (c) With halogenoalkane:

further reaction (of primary amines)

OR

Impure product/mixture of products/lower atom economy

Ignore bi-product / yield

1

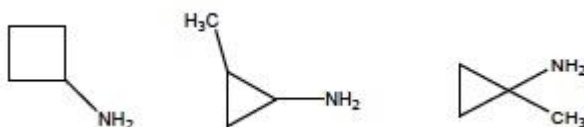
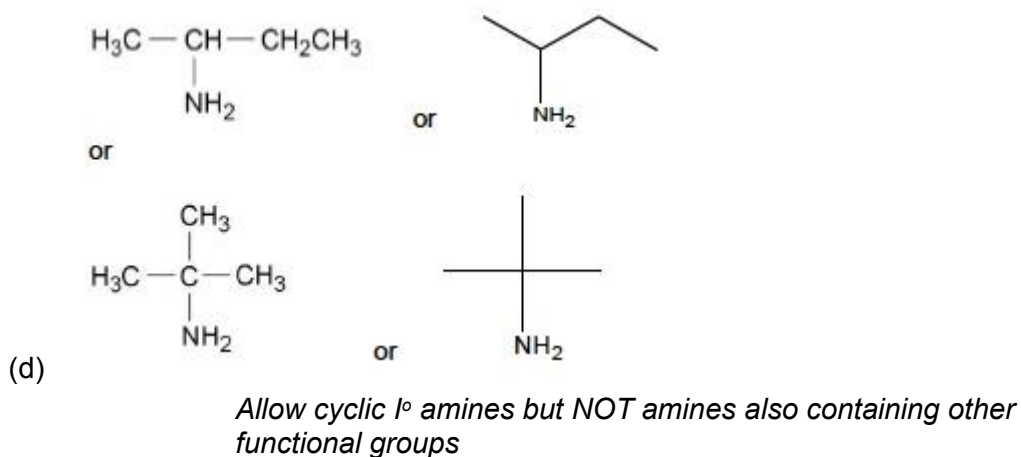
With nitriles

No further reaction

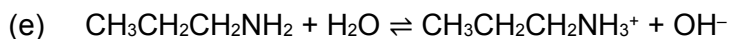
OR

Single product / higher atom economy

1



1



Allow simple arrow

Not C_3H_7

1

(green) turns blue

Allow blue-green, blue-purple

1



Not H_2

Not molecular formulae

OR



1

$\text{C}_6\text{H}_5\text{NH}_2$ present as ionic salt OR $\text{C}_6\text{H}_5\text{NH}_3^+ (\text{Cl}^-)$ OR phenyl ammonium (chloride)

Allow present as an ion

But not phenylammonium hydroxide

1

[10]

Q2.

C

Q3.

- (a) (Strength depends on availability of) lone pair on N (atom)

M1

E N (next to ring): (lp) delocalised into ring

M2

(lp) less available (to donate to or to accept a H^+)

M3

F or **G**: N (next to alkyl): (positive) inductive effect/electrons pushed to N

M4

(lp) more available (to donate to or to accept a H^+)

M5

order of increasing base strength **E**<**G**<**F**

*Or **F** is most basic **and** **E** is least basic*

M6

- (b) Intermediate compounds

Product of step 1 $C_6H_5CH_2Cl$

Allow $C_6H_5CH_2Br$

Product of step 2 $C_6H_5CH_2CN$

In steps 2 and 3, only allow marks for reagents/conditions if intermediate compounds are correct or close.

Reagents/conditions

Step 1

Cl_2 & UV

Allow Br_2 & UV

Step 2

KCN alcoholic & aq (both reqd)

Ignore temperature

Step 3

H_2 / Ni or Pt or Pd

Allow $LiAlH_4$ in (dry) ether – (with acid CE, followed by acid allow)

Not $NaBH_4$ and not Sn/HCl or Fe/HCl

2

[11]

Q4.

C

[1]

Q5.

- (a) (i) (2-)chloroethan (-1-) oyl chloride

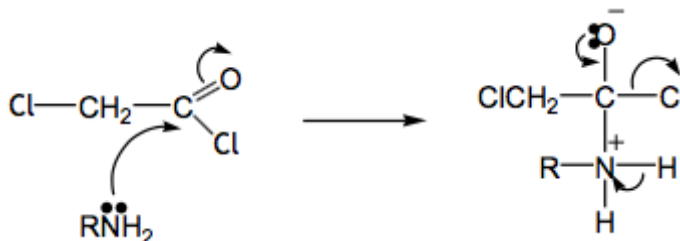
2 not required but penalise 1- or other numbers at start.

Ignore 1 in ethanoyl

Ignore hyphens, commas, spaces

1

- (ii)



M1 for arrow from lp on N to C

(or to space half way between N and C)

If full amine drawn, ignore slips except in -NH₂

M2 for arrow from C=O bond to O

Not score M2 as an independent first step, but can allow M1 for attack on C⁺ produced

If Cl lost at this stage, Max 1 for M1

M3 for structure of ion including 2 charges

M4 for 3 arrows and lp on O

- may be scored in two steps

Ignore use of RNH₂ to remove H⁺ in M4, but penalise use of Cl⁻

4

- (b) Nucleophilic substitution

Allow minor spelling errors e.g. nucleophyllic

1

- (c) 9

1

- (d) $M_r = 234(0)$

9.4 scores 2 marks

1

$$\% \text{ H} = 9.4(0)$$

$$M2 = \frac{22}{M1} \times 100$$

If $M_r = 234$ not shown, can score M1 if their answer $\times 234 =$ their no of H

1

- (e) Tertiary amine OR 3^o amine OR III^o amine

Ignore N- substituted

1

- (f) (i) If **a** given: CE=0, can only score if answer given is **b**

M1 lp on N^b or on **b**

M2 alkyl groups donate electron density or positive inductive effect or electron donating groups attached

M3 (lp on N^b) more available or protonated amine stabilised or better lp donor/H⁺ acceptor

Ignore reference to nucleophiles

*NOTE – there is NO mark for **b** alone*

Alternatives

*M1 lp on N^a or on **a***

M2 lp or electrons (on N^a) delocalised into ring /towards O in C=O

M3 (lp on N^a) less available (to bond to H⁺/accept proton)

1
1
1

(ii) Salt is ionic

Independent marks

1

(More) soluble (in blood/body fluids/water)

1

[15]

Q6.

- (a) M1 Lone pair on N labelled **b** more available / more able to be donated than lone pair on N labelled **a**

Ignore N(b) more readily accepts protons.

Ignore N(b) is stronger base.

1

M2 lp or electrons or electron density on N labelled **a**:

delocalized into (benzene) ring

QoL

1

M3 lp or electrons or electron density on N labelled **b**:

methyl / alkyl groups electron releasing or donating or (positive) inductive effect or push electrons or electron density

QoL

1

- (b) C₁₉H₂₄N₂

Any order.

1

11

1

[5]

Q7.

- (a) **M1** Benzene is more stable than cyclohexatriene

more stable than cyclohexatriene must be stated or implied
If benzene more stable than cyclohexene, then penalise M1
but mark on
If benzene less stable: can score M2 only

1

- M2** Expected ΔH° hydrogenation of C_6H_6 is $3(-120)$

$$= -360 \text{ kJ mol}^{-1}$$

Allow in words e.g. expected ΔH° hydrog is three times the
 ΔH° hydrog of cyclohexene

1

- M3** Actual ΔH° hydrogenation of benzene is

152 kJ mol⁻¹ (less exothermic)

or 152 kJ mol⁻¹ different from expected

Ignore energy needed

1

- M4** Because of delocalisation or electrons spread out or resonance

1

- (b) **No mark for name of mechanism**

Conc HNO_3

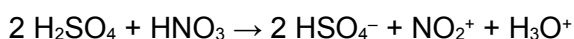
If either or both conc missing, allow one;

1

Conc H_2SO_4

this one mark can be gained in equation

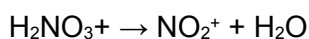
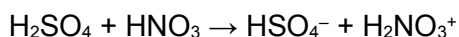
1



OR

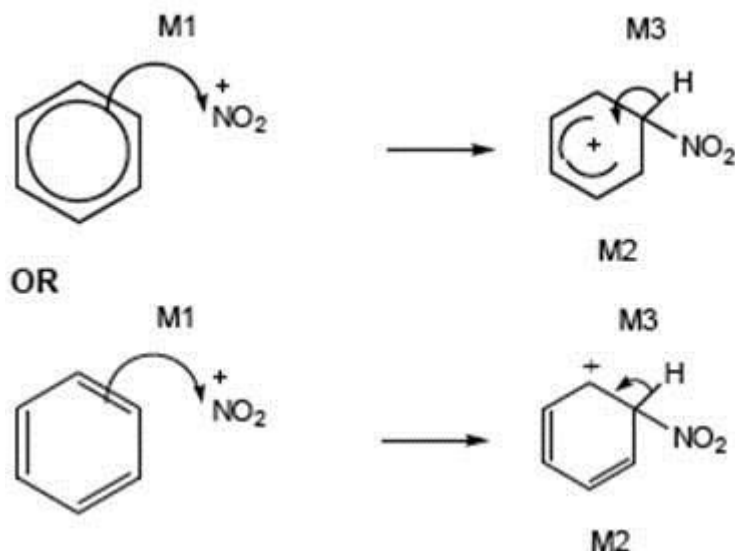


OR via two equations



Allow + anywhere on NO_2^+

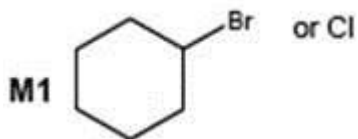
1



M1 arrow from within hexagon to N or + on N
Allow NO₂⁺ in mechanism
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
ignore base removing H in M3
+ on H in intermediate loses M2 not M3

3

(c) If intermediate compound V is wrong or not shown, max 4 for 8(c)



or chlorocyclohexane or bromocyclohexane

1

Reaction 3

M2 HBr

1

M3 Electrophilic addition

Allow M2 and M3 independent of each other

1

Reaction 4

M4 Ammonia if wrong do not gain M5

1

Allow M4 and M6 independent of each other

M5 Excess ammonia or sealed in a tube or under pressure

1

If CE e.g. acid conditions, lose M4 and M5

M6 Nucleophilic substitution

1

- (d) Lone or electron pair on N

No marks if reference to "lone pair on N" missing

1

Delocalised or spread into ring in U

1

Less available (to accept protons) or less able to donate (to H⁺)

1

[19]

Q8.

D

[1]

Q9.

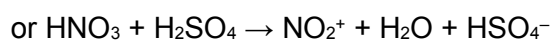
- (a) (i) conc HNO₃

1

conc H₂SO₄

allow 1 for both acids if either conc missing

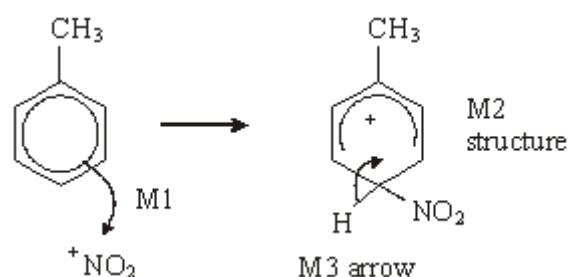
1



1

- (iii) electrophilic substitution CH₃

1



horseshoe must not extend beyond C2 to C6 but can be smaller
+ must not be too close to Cl

3

- (b) Sn or Fe / HCl (conc or dil or neither)
or Ni / H₂ not NaBH₄ LiAlH₄

1

- (c) (i) NH₃

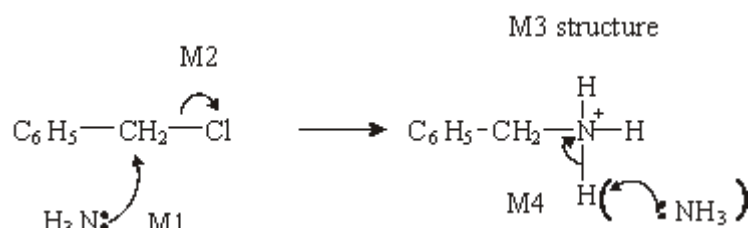
1

Use an excess of ammonia

1

(ii) nucleophilic substitution

1



4

[15]

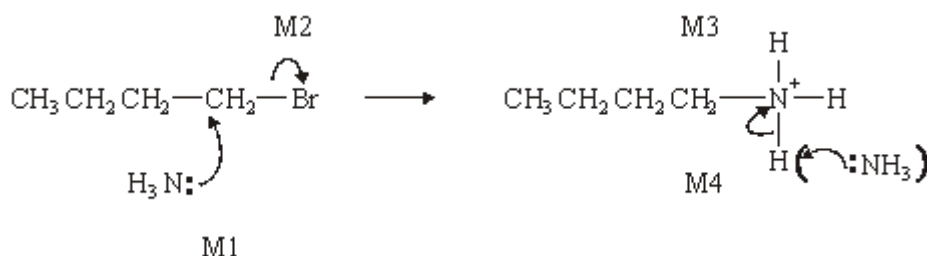
Q10.

B

[1]

Q11.

(a) Nucleophilic substitution



1

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⁺)

4

(b) Step 1 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$ 1

$\text{CH}_3\text{CH}_2\text{CH}_2\text{Br} + \text{KCN} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CN} + \text{KBr}$ balanced

1

(or CN⁻) (or Br⁻)
(not HCN)

1

Step 2 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN} + 2\text{H}_2 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$
(or 4[H])

1

(c) (i) Lone pair (on N) (in correct context)

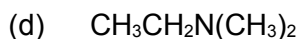
1

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



1

[12]

Q12.

- (a) Cyclohexane evolves 120 kJ mol^{-1}

$\therefore$ (expect triene to evolve) 360 kJ mol^{-1} (1) or 3×120

$$360 - 208 = 152 \text{ kJ (1) NOT 150}$$

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

4

- (b) (i) phenylamine weaker (1)

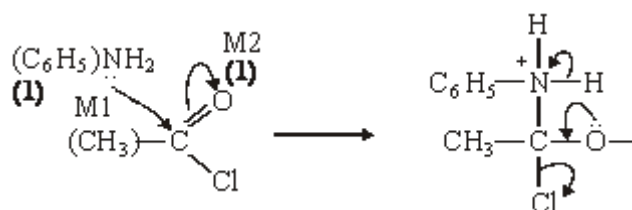
if wrong no marks

lone pair on N (less available) (1)

delocalised into ring (1) or "explained"

3

- (ii) addition – elimination (1)



structure (1) M3

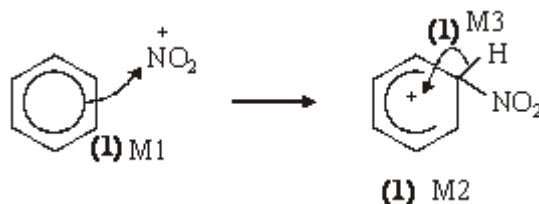
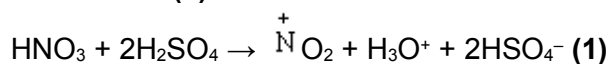
3 arrows (1) M4

N-phenyl ethanamide (1)

6

- (iii) conc HNO_3 (1)

conc H_2SO_4 (1)



6

- (iv) peptide / amide (1)

NaOH (aq) (1)

HCl conc or dil or neither
H₂SO₄ dil NOT conc
NOT just H₂O

2

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 ΔH 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 $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{NO}_2^+ + \text{HSO}_4^- + \text{H}_2\text{O}$
ignore side chain in mechanism even if wrong
arrow for M1 must come from inside 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]

Q13.

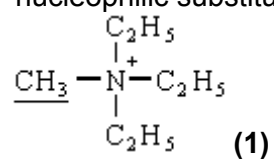
- (a) (i) H⁺ or proton acceptor (1)
 $\text{CH}_3\text{NH}_2 + \text{H}_2\text{O} (\rightleftharpoons) \text{CH}_3^+\text{NH}_3 (+) \text{OH}^-$ (1)
- (ii) CH₃NH₃Cl or HCl (1)
*Or any ammonium compound or strong acid
name or formula*
- (iii) extra OH⁻ reacts with CH_3^+NH_3
or reaction / equilibrium moves to left
or ratio salt / base remains almost constant (1)
Any 2
- (b) lone pair (on N accepts H⁺) (1)
CH₃ increases electron density (on N)
donates / pushes electrons

5

has positive inductive effect (1)

2

(c) nucleophilic substitution (1)



2

[9]

Examiner reports

Q1.

- (a) This was answered correctly by almost two-thirds of the students. The most common error was to confuse B and C.
- (b) This question discriminated well and the best students drew three correct skeletal formulas. Cyclic secondary amines were accepted as long as there was no other functional group present, and one cyclic amine was sometimes included in place of the isomer with the branched propyl group. A common error was to draw primary amines based on branched alkyl groups.
- (c) Both marks were gained by the 28.9% of the students who stated that further substitution reactions would occur following the formation of a primary amine from a halogenoalkane, and also that no further reaction would occur when primary amines were formed from nitriles. The second mark was less often gained, sometimes because students made no comment about nitriles at all.
- (d) This was answered well although 12.4% of the students did not attempt the question.
- (e) Many students were able to write a correct equation for the reaction between propylamine and water. However, some incorrectly suggested that the weak base would turn the indicator purple. Examiners noted that the use of litmus was sometimes described instead of Universal Indicator. The frequency with which this occurred suggests that some students do not necessarily make a distinction between U. I. and litmus.
- (f) A good proportion of students gained the first mark for a correct equation. Only 7.7% could describe the formation of the phenylammonium ion and so explain the solubility of phenylamine in the aqueous acidic solution.

Q2.

A was the commonest incorrect response. 58.3% of students realised that electron-releasing alkyl groups increase the availability of the lone pair on N, making amines more basic than ammonia (D).

Q3.

- (a) The full range of marks was seen and included some excellent answers. Other responses did not contain accurate descriptions of the effect of the attached groups on the availability of the lone pair on the nitrogen atom. The idea that, for nitrogen atoms directly attached to the benzene ring, the lone pair was delocalised into the ring was often poorly explained. The (positive) inductive effect of alkyl groups was much better described.
- (b) Some excellent answers were seen, but overall this was not answered well. The fact that about 8% of students made no attempt at this part of the question perhaps indicated that a small number of students were short of time. Some students, confused by the presence of a benzene ring, started with nitration. This rarely led to any marks. For those who chose the correct route, the two intermediates were often correctly identified. The use of chlorine or bromine in UV in the first step was usually well known but use of the reagent KCN in a mixed aqueous/alcoholic solvent was less often correct in the next step. The expected reducing agent/condition for the

final step was hydrogen with a nickel or platinum catalyst. LiAlH_4 in dry ether is not required knowledge for this specification, but was an acceptable answer.

Q5.

The IUPAC name in part (a)(i) proved harder than expected with answers including 1-chloro or ethyl. The mechanism in part (a)(ii) was well known with over half of students gaining full marks. There was a wide range of answers to part (d) with both the number of hydrogens and the overall M_r proving harder than expected, but, even so, nearly half of all students scored both marks. Many students knew (e) was tertiary but some thought it was an amide rather than an amine.

Part (f)(i) was generally well done and in the correct responses there was a fairly even distribution between those describing why b is a stronger base or why a is a weaker base. Part (f)(ii) proved more difficult and only the best students scored any marks. The term salt was given in the question and so just that link was not credited. Few stated that the ionic character of the salt would make it more water-soluble than lidocaine itself.

Q6.

Very few students scored all three marks for part (a). The ability of either nitrogen atom to be protonated depended on the availability of the lone pair and this needed to be mentioned for the first mark. The inductive effect of the alkyl groups on the nitrogen labelled b was the most often scored mark. Many failed to mention that the lone pair on the nitrogen labelled a would be delocalised into the benzene ring, often stating that the benzene rings are electron withdrawing or simply that there were delocalised electrons present.

Part (b) was poorly answered with a structural formula sometimes being given or alternatively a molecular formula but with an incorrect number of hydrogen atoms. The number of ^{13}C peaks was also found difficult and eight was a common wrong answer.

Q7.

In part (a), although most candidates scored at least half marks, some candidates did not use the data as requested. Some answers also referred to cyclohexatriene but went on to talk about one double bond.

Part (b) was well done, especially the mechanism. The most common errors were to omit *concentrated* for either or both acids or to omit the positive charge on the H_2NO_3^+ when writing two equations.

The synthesis in part (c) was a stretch and challenge question and was, as expected, very discriminating. There were some excellent answers but also many which failed to score.

Many candidates were unable to identify V and those who did often named it as a halobenzene even if they drew a correct structure. Preparation of the amine by nucleophilic substitution using an excess of ammonia was credited in Reaction 4 even if the answers to V and Reaction 3 were wrong.

A surprising number of candidates thought a base was a proton donor. Some otherwise good answers did not score as they failed to mention the lone pair on the nitrogen atom.

Many also simply stated that amine U contained delocalised electrons but failed to explain how involvement of the lone pair on nitrogen with these electrons lowered the base strength.

Q9.

Part (a) was answered well by most candidates, but many did not note that both acids used in nitration are concentrated. Weaker candidates were unable to name the mechanism correctly and several lost marks by drawing the curly arrow going to the oxygen rather than the nitrogen of NO_2^+ , by drawing the intermediate structure carelessly with the + charge shown too close to the tetrahedral carbon or by drawing the curly arrow showing the loss of H^+ the wrong way round.

Surprisingly, part (b) was badly answered: many incorrectly suggested NaBH_4 and in part (c) the need for an excess of ammonia was not well known. The first stage in the mechanism was answered well, but many were unable to show loss of H^+ correctly from the protonated amine.

Q11.

Although nucleophilic substitution reactions of haloalkanes appear both in CHM3 and in CHM4, a disappointing number of candidates was unable to name the mechanism correctly. Too many also showed the ammonia molecule with a negative charge. Curly arrows were drawn well by most except the careless. In part (b), a large number suggested that the reagent required in Step 1 was HCN rather than an ionic cyanide such as KCN . The equation in Step 2 was usually correct.

Part (c)(i) was usually well known although the simple statement "because of the inductive effect" was insufficient since it does not make it clear that the alkyl group has a positive inductive effect. A surprising number of candidates wrote NaOH rather than a strong acid or an ammonium or amine salt in part (c)(ii). Part (d) was answered correctly only by the better candidates.

Q12.

In part (a), not all candidates noted the requirement in the question to "Use the data". The numerical difference of 152 kJ mol^{-1} between the expected enthalpy of hydrogenation of -360 kJ mol^{-1} and the actual value of -208 kJ mol^{-1} was rarely noted. Weaker candidates also thought that the data given was of the energy required to cause the reaction, rather than that evolved in the reaction. In part (b), weaker candidates muddled the expected addition-elimination reaction of an acid chloride and an amine with a Friedel Craft's substitution in the benzene ring and frequently gained no marks for the section. The correct name for the product, N-phenylethanamide was rarely seen. Part (c) was better answered; most candidates were able to discuss nitration correctly and the mechanism was better answered than that in part (b)(ii). The amide or peptide link was not always named correctly in part (iv) and many did not state that acidic or alkaline hydrolysis is required to break the bond.

Q13.

Most were able to state in part (a) that a Brønsted-Lowry base is a proton acceptor, but writing an equation to illustrate this proved more difficult. Most of the better candidates were able to deduce that the basic buffer could be created by adding either a salt of methylamine with a strong acid such as hydrochloric or by adding the acid itself, but giving a qualitative explanation of the action of a basic buffer proved difficult for most candidates.

In part (b), the increase of electron density on the nitrogen and the greater availability of the lone pair were not always made clear.

Part (c) was rarely answered correctly. The use of a large excess of bromoethane was not noted and most answers gave the cation $[\text{CH}_3(\text{C}_2\text{H}_5)\text{NH}_2]^+$ which is formed after one substitution rather than the quaternary ammonium salt required.