Suggested Answers

VCE Chemistry 2009 Year 12 Trial Exam Unit 3

Multiple Choice Answers – Section A

Question 1

A. According to the data booklet – Table 11.

Indicator	pH range of colour change
Methyl red	4.2–6.3
Phenol red	6.8–8.5
Phenolphthalein	8.3–10.0
Bromthymol blue	6.0–7.6

$Na_2CO_3(aq)$ is a basic solution so the pH in the titration flask will initially be > 7. As the acid is added to the $Na_2CO_3(aq)$ the pH drops. The endpoint of the reaction occurs when all the basic solution has been neutralised by the acid, so the indicator colour should change colour after the pH drops below 7.

Methyl red is the indicator listed that only changes colour once the pH is below 7.

Question 2

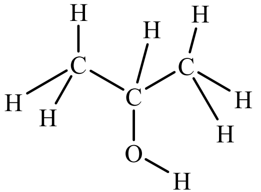
B. An aqueous solution of potassium dichromate is orange because it transmits orange light, i.e. allows orange light to pass through it. The orange colour of the solution appears in the presence of visible light because that is what remains after complementary colours to orange are absorbed by the solution. The complementary colour to orange, wavelength 580-620 nm, is blue, wavelength 440-470 nm. It is only because wavelengths in the blue region are absorbed that the solution appears orange. The determination of the concentration of the solution would require measuring the absorbance of the solution using a wavelength in the blue region and comparing this absorbance with the absorbances, using the same wavelength, of a series of standards.

Question 3

C. The fact that the ^1H NMR spectrum shows only two peaks indicates two different H environments. The peak area ratio of 9:1 suggests 9 H atoms in one environment and 1 H atom in the other environment.

ethanol – CH_3CH_2OH – 3 different H environments, hence 3 peaks in the ratio 3:2:1

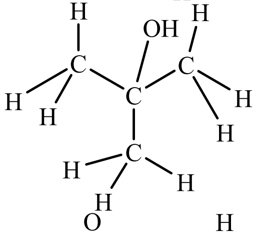
propan-2-ol – $(CH_3)_2CHOH$ –



3 different H environments

3 peaks in the ratio 6:1:1

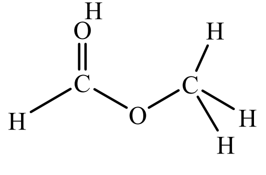
methylpropan-2-ol – $(CH_3)_3OH$ -



2 different H environments

2 peaks in the ratio 9:1

methyl methanoate – $HCOOCH_3$ -



2 different H environments

2 peaks in the ratio 3:1

Hence methylpropan-2-ol is the only possible option. However the ^1H NMR spectrum is not necessarily that of methylpropan-2-ol because methylpropane also produces a ^1H NMR spectrum with 2 peaks in the ration 9:1. Chemical shift data could be used to distinguish the two spectra.

Question 4

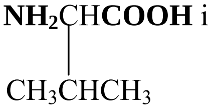
D. The structure shown is that of a nucleotide in DNA made up of a phosphate group, deoxyribose and a nitrogen base.
It is clearly not DNA or RNA but is certainly part of DNA.

Question 5

B. The nucleotide will not form any disulfide links because it contains no sulfur.
As part of the primary structure of DNA polynucleotide it will form two covalent bonds at the 5'-phosphate group on one nucleotide and 3'-hydroxyl, -OH, on another nucleotide via condensation polymerisation.
Hydrogen bonding between complementary polynucleotides maintains the secondary structure of DNA. The hydrogen bonding occurs between the nitrogen bases on the polynucleotides. **Adenine (A), the nitrogen base on the nucleotide shown, forms two hydrogen bonds with its complementary nitrogen base thymine (T).** The other complementary base pairing is guanine (G) and cytosine (C) between which three hydrogen bonds form.

Question 6

D. Consider the data:
Absorption band centred close to 3400 cm^{-1} → N-H (3350-3500 cm^{-1}) as in NH_2 group
^1H chemical shift close to 11 ppm → RCOOH, i.e. carboxyl group (11.5 ppm)
Both of these pieces of data suggest a compound containing the amino and carboxyl groups – most likely an amino acid.
This is further confirmed by the ^{13}C chemical shifts:
55 ppm → NH_2 (35-70 ppm); 170 ppm → COOH (160-185 ppm).
Ethanamine – $CH_3CH_2NH_2$, propanoic acid – CH_3CH_2COOH, and ethyl ethanoate ($CH_3COOCH_2CH_3$) are not consistent with this data.
Valine $\mathbf{NH_2}$CH**COOH** is consistent with the data.



$$\begin{array}{l} \mathbf{NH_2}CH\mathbf{COOH} \\ \quad\;\; | \\ CH_3CHCH_3 \end{array}$$

Question 7

C. Oxygen – O_2; ozone – O_3
Container X: $n(O_2)$ = 16 g / 32 g mol^{-1}
= 0.50 mol
n(atoms) = 2 x 0.50 = 1.0 mol
Container Y: $n(O_3)$ = 24 g / 48 g mol^{-1}
= 0.50 mol
n(atoms) = 3 x 0.50 = 1.5 mol
Since both containers are of the same volume and at the same temperature, the pressure is each container is directly dependent on the number of mol of gas molecules present. Since both containers hold the same number of molecules, they will both be at the **same** pressure.
Since each ozone molecule contains 3 atoms, as against 2 atoms in each oxygen molecule, there are more atoms in container Y.

Question 8

B. The equation $ClO_2(aq) + H^+(aq) + I^- \rightarrow I_2(aq) + Cl^-(aq) + H_2O(l)$ can be balanced by developing the two half-equations.

Oxidation: $2I^-(aq) \rightarrow I_2(s) + 2e^-$

Reduction: $ClO_2(aq) + 4H^+(aq) + 5e^- \rightarrow Cl^-(aq) + 2H_2O(l)$

To get the overall redox equation, equalise the electrons by multiplying the oxidation half-equation by 5 and the reduction half-equation by 2. This gives the overall equation

$2ClO_2(aq) + 8H^+(aq) + 10I^- \rightarrow 5I_2(aq) + 2Cl^-(aq) + 4H_2O(l)$.

The oxidant is ClO_2 – it oxidises I^- to I_2 (oxidation number of I increases from -1 to 0) and is itself reduced to Cl^- (oxidation number of Cl decreases from +4 to -1).

The **reductant is I^-** – it reduces ClO_2 to Cl^- (oxidation number of Cl decreases from +4 to -1) and is itself oxidised to I_2 (oxidation number of I increases from -1 to 0).

Question 9

D. Mass spectroscopy can be used to determine the molecular mass of the compound and to identify molecular fragments.

Nuclear magnetic resonance spectroscopy can be used to determine hydrogen environments (^1H NMR) and carbon environments (^{13}C NMR).

Infrared spectroscopy can be used to identify functional groups and bonds present in a molecule.

Atomic absorption spectroscopy is not used because it is generally used for the quantitative analysis of metals.

Question 10

D. When a pipette is used accurately, the initial level of the liquid is such that the **bottom of the meniscus is line with the calibration mark.** Such is the calibration of a pipette that when the aliquot is allowed to run smoothly from the pipette, a small amount of the liquid will remain, due to surface tension effects, in the tip of the pipette. Hence **alternative D** is the correct representation

Question 11

A. Gravimetric analysis is most often associated with the collection and weighing of a precipitate. Whilst a precipitate can be collected by filtration or decanting, the use of a filter funnel is not essential. However an electronic balance is essential if the weight of the precipitate is to be measured accurately.

Question 12

B. The empirical formula of styrene, C_8H_8, is CH, and the empirical formula of 1,3-butadiene, C_4H_6, is C_2H_3.

Comparison of the C:H ratios – styrene 1:1 1,3-butadiene 1:1.5 SBR 1:1.3

SBR has a higher C:H ratio than styrene but a lower C:H ratio than 1,3-butadiene. This suggests that SBR contains more 1,3-butadiene that styrene. Consider the mole ratios suggested in the alternatives.

A. If the ratio was 1:1 the C:H ratio would be
   (8+4) : (8+6) → 12 : 14 → 6:7 → 1:1.16

B. If the ratio was 1:3 the C:H ratio would be
   (8 + 3x4) : (8 +3x6) → 20:26 → **10:13** → **1:1.3**

C. If the ratio was 3:1 the C:H ratio would be
   (3x8 + 4) : (3x8 + 6) → 28:30 → 14:15 → 1:1.07

D. If the ratio was 10:13 the C:H ratio would be
   (10x8 + 13x4) : (10x8 + 13x6) → 132:158 → 1:1.2

Question 13

D. The smallest alkanol, with a molar mass of 58 g mol^{-1} could be 1-butanol $CH_3CH_2CH_2CH_2OH$ or the other isomer of $C_4H_{10}O$ with a terminal –OH group in 2-methylpropan-1-ol, $(CH_3)_2CHCH_2OH$. Since the mixture is part of an homologous series, i.e. successive members differ by CH_2, and molecules of 1. contain 4 C atoms, then molecules of 2. will contain 5 C atoms, molecules of 3. will contain 6 C atoms, whilst molecules of 4 and 5 will contain 7 and 8 C atoms respectively.

Considering the alternatives.

A. The most abundant alkanol in the mixture is the one with the highest peak area on the chromatogram. This is alkanol 4., not alkanol 5.

B. Alkanol must contain 6 C atoms and could be 1-hexanol, not 1-heptanol.

C. Alkanol 1. with the shortest retention time is ‘least’ strongly attracted to the mobile phase.

D. Alkanol 4. must contain 7 C atoms and could 1-heptanol or one of the alkanol isomers of $C_7H_{16}O$.
3,4-dimethylpentanol $CH_3CH(CH_3)CH(CH_3)CH_2CH_2OH$ which has the molecular formula $C_7H_{16}O$ is one such isomer.

Question 14

B. The main steps in the creation of a DNA profile are

1. Extract / isolate a DNA sample, e.g.. from a blood spot, piece of hair etc
2. Amplify the DNA using PCR (polymerase chain reaction).
3. Cut up the DNA using special enzymes called restriction enzymes which recognise specific sequences on the DNA and cut at specific sites on the recognised sequence. This produces fragments of DNA.
4. Separate the DNA fragments using gel electrophoresis
5. ‘Light up’ or probe the DNA fragments using radioactive or fluorescent dyes.

Gas chromatography is normally not part of this process.

Question 15

C. $CH_3CH_3(g) + Cl_2(g) \rightarrow CH_3CH_2Cl(g) + HCl(g)$

Consider the *m*/*e* ratio of the species in the alternatives

A. $CH_3{}^{35}Cl^+ = 50$; $CH_3{}^{35}Cl_2{}^+ = 85$

B. $CH_3CH_2{}^{35}Cl = 64$; $CH_2{}^{35}ClCH_2{}^{37}Cl = 100$

C. $CH_3CH_2{}^{35}Cl^+ = 64$ and $CH_3CH_2{}^{37}Cl^+ = 66$

D. $C_2H_5{}^{35}Cl^+ = 64$ and $C_2H_3{}^{37}Cl^+ = 64$

Since the isotopic composition of chlorine is approximately 75 percent ${}^{35}Cl$ and 25 percent ${}^{37}Cl$, there are two possible molecular ions for CH_3CH_2Cl, with, as the height of the peaks mass spectrum indicates, the relative proportions of $CH_3CH_2{}^{35}Cl$ and $CH_3CH_2{}^{37}Cl^+$ is 3 : 1.

Question 16

A. Antibodies, and other organ specific proteins, can act as markers for disease and organ damage.

Since enzymes are proteins, then telomerase is an enzyme.

Question 17

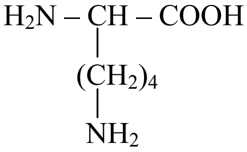
D. If H_2SO_4 is the oxidant, it will cause oxidation and be itself reduced. Hence when it acts as an oxidant one of the atoms in the molecule must decrease in oxidation number. Consider the oxidation numbers

H_2SO_4 – H = +1, S = +6, O = -2
H_2S – H = +1, S = -2, hence H_2S is a possible product.
S – S = 0, hence S is a possible product.
SO_2 – S = +4, O = -2, hence SO_2 is a possible product.
SO_3 – S = +6, O = -2; no change in oxidation number compared to H_2SO_4, hence SO_3 is **not** a possible product.

Question 18

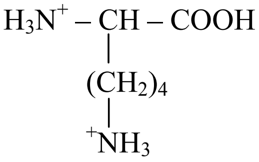
D. The structural formula of lysine, an amino acid, is in the data book, Table 8.
In a solution of pH 2 (acidic), the amino acid will act as a base and each of the two basic amino groups will accept a proton

i.e.



$H_2N-CH(-(CH_2)_4-NH_2)-COOH$

will be converted to



$H_3N^+-CH(-(CH_2)_4-{}^+NH_3)-COOH$

and assume an overall charge of +2.

Question 19

B. The bonds associated with the absorption bands can be identified from Table 7 in the Data Booklet.

3350-3500 cm^{-1} → N–H bond
1670-1750 cm^{-1} → C=O bond
1610-1680 cm^{-1} → C=C bond
2850-3300 cm^{-1} → C–H bond

Checking the structural formulae for the four nucleic acids in Table 10 in the Data Booklet, the bond not present in adenine but present in the other three is C=O.

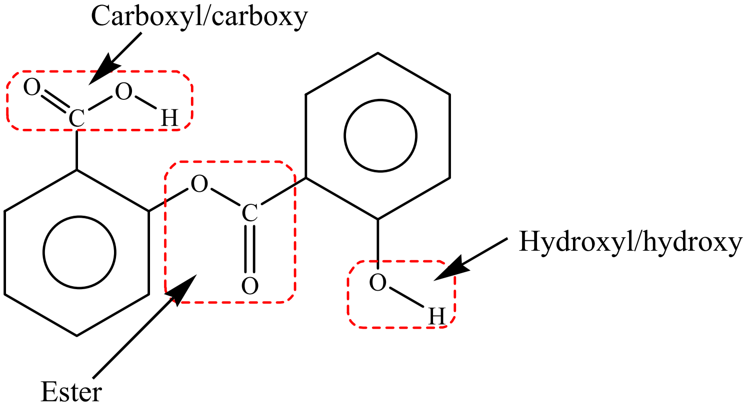
Question 20

C. 2-aminopropane – $CH_3CHNH_2CH_3$
$M(CH_3CHNH_2CH_3) = 59.0\ g\ mol^{-1}$
Since one mol (59.0 g) of $CH_3CHNH_2CH_3$ contains $6.02 x 10^{23}$ molecules
Mass of one $CH_3CHNH_2CH_3$ molecule $= 59.0 / 6.02 x 10^{23}$
$= 9.80 x 10^{-23}$ g

Short Answers (Answers) – Section B

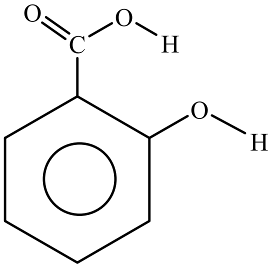
Question 1

a.



❶ for each correct combination of circled functional group and name.

b. Since the ester functional group is formed by reaction between a carboxyl and an hydroxyl functional group, there is only one reactant – salicylic acid – represented by either



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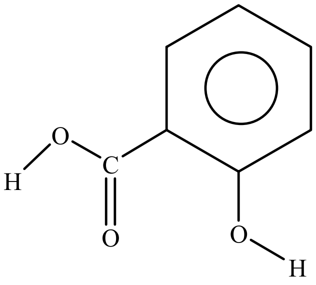
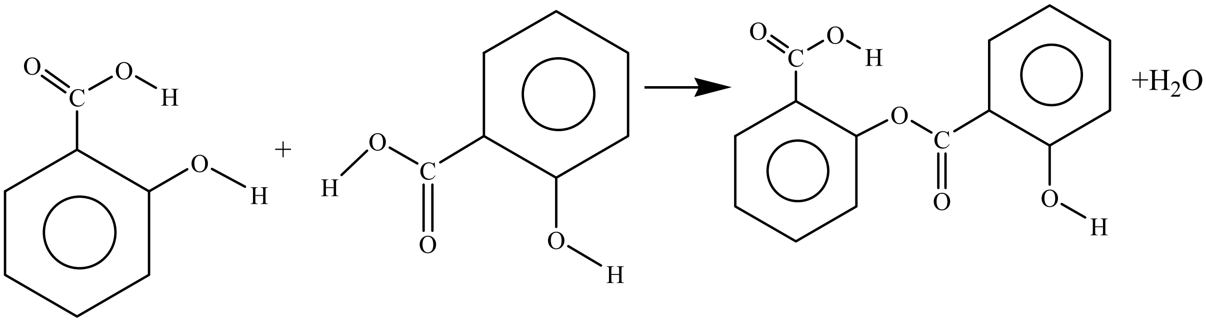


❶❶

The esterification reaction would be



c. $C_{14}H_{10}O_5$ ❶

N.B. The benzene ring, by itself C_6H_6, loses one H for each group attached to the ring. Hence in this molecule each of the two benzene rings is C_6H_4.

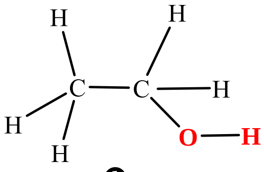
d. $C_{14}H_9O_5^+$❶

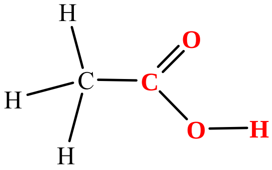
The relative molecular mass of Salsalate is 258 (14 x 12.0 + 10 x 1.0 + 5x16.0). Hence its molecular ion, $C_{14}H_{10}O_5^+$, peak would be expected to show at an *m*/*e* ratio of 258. So a peak at 257 would be associated with an ion with one less H atom

e. A peak at an *m*/*e* ratio one higher than the molecular ion suggests it is associated with the presence of an isotope of one of the elements making up the compound in a small proportion of the molecules. Most likely carbon-13, ^{13}C. ❶

Question 2

a. X - ethanal Y - ethanoic acid





❶ ❶

❶ ❶

Since $C_4H_8O_2$ may be the molecular formula of a carboxylic acid or an ester, the fact that two reactants X and Y are involved suggests it is an ester. Since the starting material is C_2H_4, X and Y are ethanol and ethanoic acid respectively.

b. Bonds in molecules stretch *or* bend *or* vibrate *or* bond angle changes ❶

c. 1610-1680 cm^{-1}, ❶ associated with a C=C double bond ❶ would be present only in ethene $CH_2=CH_2$

Alternatively

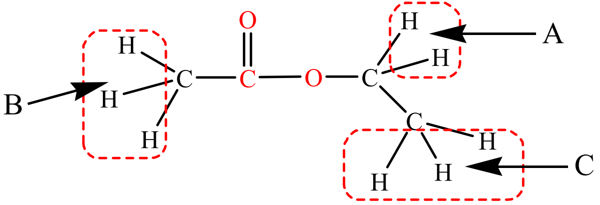
2500-3300 cm^{-1}, associated with O-H in acids, would only be present in Y (CH_3COOH).

3200-3550 cm^{-1}, associated with O-H in alcohols, would only be present in X (CH_3CH_2OH)

d. X – CH_3CH_2OH – is an alcohol and the O-H bond will show an absorption band of 3200-3550 cm^{-1}. ❶

X – CH_3COOH – is a carboxylic acid and the O-H bond will show an absorption band of 2500-3300 cm^{-1}. ❶

e. $C_4H_8O_2$ is ethyl ethanoate, $CH_3COOCH_2CH_3$, represented by the structural formula



Peak A – split into a quartet, must be due to the H atoms on the CH_2 group ❶, the signal for which is split into a quartet by the 3 H atoms on the adjacent CH_3 group.

Peak B – a singlet, must be due to the H atoms on the CH_3 group to the left of the ester group ❶, the signal for which is not split because there are no H atoms on the adjacent C atom.

Peak C – split into a triplet, must be due to the H atoms on the CH_3 group bonded to CH_2 ❶, the signal for which is split into a triplet by the 2 H atoms on the adjacent CH_2 group.

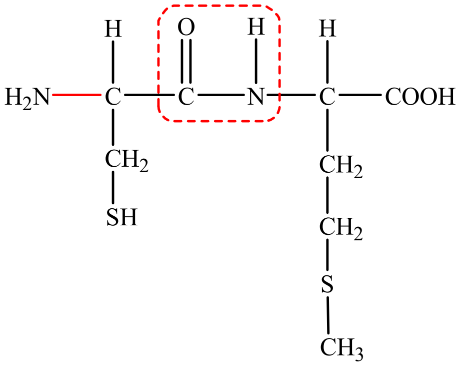
f. methyl propanoate ❶, $CH_3CH_2COOCH_3$ ❶
Isomers of $C_4H_8O_2$ – other than ethyl ethanoate, $CH_3COOCH_2CH_3$, include
$CH_3CH_2CH_2COOH$, butanoic acid, – 4 peaks on the ^1H NMR
$(CH_3)_2CHCOOH$, 2-methyl propanoic acid, – 3 peaks on the ^1H NMR, a singlet (COOH), a doublet $(CH_3)_2$ and a multiplet (CH)
$CH_3CH_2COOCH_3$,methyl propanoate – 3 peaks on the ^1H NMR, a quartet, a triplet and a singlet.
$HCOOCH_2CH_2CH_3$, 1-propyl methanoate – 4 peaks on the ^1H NMR, a singlet (HCOO), a triplet (CH_2), a multiplet (CH_2) and a triplet (CH_3).

$HCOOCH(CH_3)_2$, 2-propyl methanoate – 3 peaks on the ^1H NMR, a singlet (HCOO), a multiplet (CH) and a doublet $(CH_3)_2$.

Question 3

a. cysteine. ❶

b. ❶❶



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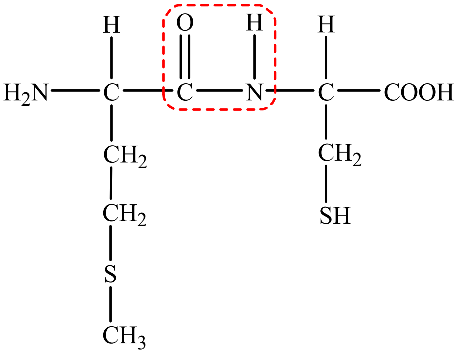


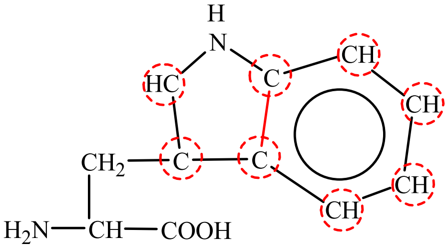
c. An amino group $–NH_2$, reacts with a carboxyl group –COOH, to produce a peptide group –CONH–. ❶

d. Covalent bonding. ❶

e. The secondary structure is maintained by hydrogen bonding ❶ between the H on one peptide group and the O on a different peptide group ❶ in the protein chain.

f. i Essential amino acids are not synthesised in the body and so must be part of the diet. ❶

ii $C_{11}H_{12}N_2O_2$ ❶



g. Gently heating the protein in a dilute solution of hydrochloric acid causes hydrolysis reactions at the peptide links and so separates the protein into its constituent amino acids which can then be separated using chromatography. ❶

Question 4

a. i Linoleic acid, $C_{17}H_{29}COOH$, has the molecular formula $C_{18}H_{30}O_2$ (from data book). Since a saturated fatty acid with 18 C atoms has the molecular formula $C_{18}H_{36}O_2$, linoleic acid is unsaturated and each molecule contains 3 C=C double bonds. One I_2 molecule reacts across each double bond.

$n(C_{18}H_{30}O_2)$ = 100 g / 278 g mol^{-1}
= 0.360 mol ❶
$n(I_2)$ reacting = 3 x $n(C_{17}H_{30}O_2)$
= 3 x 0.360 ❶
= 1.08 mol
$m(I_2)$ required = 1.08 mol x 254 g mol^{-1}
= 274 g ❶

Iodine number of linoleic acid is 274

ii. Arachidic acid, $C_{19}H_{39}COOH$, has the molecular formula $C_{20}H_{40}O_2$ and so is saturated, i.e. has no C=C double bonds and does not undergo an addition reaction with iodine. ❶

b. i. Glycerol, $C_3H_8O_3$ ❶

ii. $C_{15}H_{29}COOH(l) + CH_3OH(l) \rightarrow C_{15}H_{39}COOCH_3(l) + H_2O(l)$ ❶❶

The formula for palmitoleic acid is obtained from the data booklet (Table 9).

c. C_2H_6O / CH_3CH_2OH ❶, i.e. ethanol

d. The use of crops such as corn for the production of bio fuels means that if land normally used to produce food is dedicated to the production of biofuels, there will be less food produced and the price of basic foodstuffs will increase. ❶

e. The sharp falls in the price of oil, and hence petrol. ❶

Question 5

$NH_4^+(aq)$	+	$OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$	[1]
in 2.75 g of fertiliser		*100 mL of 0.108 M NaOH*	
$NaOH(aq)$	+	$HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$.	
excess from [1.]		*14.1 mL of 0.105 M*	[2.]

a. n(NaOH) remaining = n(HCl) used
= c(HCl) x V(HCl)
= 0.105 x $14.1\text{x}10^{-3}$
= **$1.48\text{x}10^{-3}$ mol** ❶

b. n(NaOH) required = n(NaOH) supplied – n(NaOH) in excess
= 0.108 x $100\text{x}10^{-3} - 1.48\text{x}10^{-3}$
= $1.08\text{x}10^{-2} - 1.48\text{x}10^{-3}$
= **$9.32\text{x}10^{-3}$ mol** ❶

c. n(N) in sample = $n(NH_4^+)$ = n(NaOH) required
= $9.32\text{x}10^{-3}$ mol ❶
m(N) in sample = n(N) x m(N)
= $9.32\text{x}10^{-3}$ x 14.0
= 0.130 g ❶
% N in sample = [m(N) / m(sample)] x 100
= [0.130 / 2.75] x 100
= **4.74 %** ❶

d.

Error	Calculated % N too high	No effect on calculated % N	Calculated % N too low
i. A small amount of the cooled solution is spilt prior to the titration.	✓ ❶		
ii. The burette is rinsed with water immediately before adding the acid prior to the titration.			✓ ❶
iii. Traces of fertiliser remain in the weighing bottle after transfer to the 0.108 M NaOH.			✓ ❶

i. This will lead to an **increase** in the calculated amount of nitrogen.
A smaller *V*(HCl) will be required (less OH^- to react with) → a smaller calculated *n*(OH^-) remaining → a larger calculated *n*(OH^-) reacting with NH_4^+ → a larger calculated *n*(NH_4^+) → a larger *n*(N) → a larger *m*(N) → a larger % N

ii. This will lead to a **decrease** in the calculated amount of nitrogen.
A larger *V*(HCl) will be required (concentration decreased by water) → larger calculated *n*(OH^-) remaining → smaller calculated *n*(OH^-) reacting with NH_4^+ → smaller calculated *n*(NH_4^+) → smaller *n*(N) → smaller *m*(N) → a smaller % N

iii. This will lead to a **decrease** in the calculated amount of nitrogen.
Because there is less than 2.75 g (say 2.72 g) of fertiliser actually added to the NaOH(aq), the calculations resulting from the analysis will give the actual mass of N in the 2.72 g of fertiliser.
However in calculating % N = *m*(N) [in 2.72 g] / 2.75 g] x 100, the division by the assumed 2.75 g will lead to a lower than true % N

Question 6

a. $BaO(s) + H_2SO_4(aq) \rightarrow BaSO_4(s) + H_2O(l)$ ❶
$MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$ ❶

b. ***n*($BaSO_4$)** produced = 0.237 g / [233.4 g mol^{-1}]
= **1.02×10^{-3} mol**
So ***n*(BaO)** reacting = **1.02×10^{-3} mol**
***m*(BaO)** in sample = 1.8×10^{-3} mol x [153.3 g mol^{-1}]
= **0.156 g** ❶
***m*(MgO) in sample = 0.952 - *m*(BaO)**
= 0.952 – 0.156
= **0.796 g** ❶
***n*(MgO)** present = 0.796 g / [40.3 g mol^{-1}]
= **1.97×10^{-2} mol** ❶
***n*(Mg^{2+})** in 500 mL of solution = *n*(MgO)
= **1.97×10^{-2} mol**
***c*(Mg^{2+})** in sample = 1.97×10^{-2} mol / 0.500 L
= **0.0394 mol L^{-1}** ❶

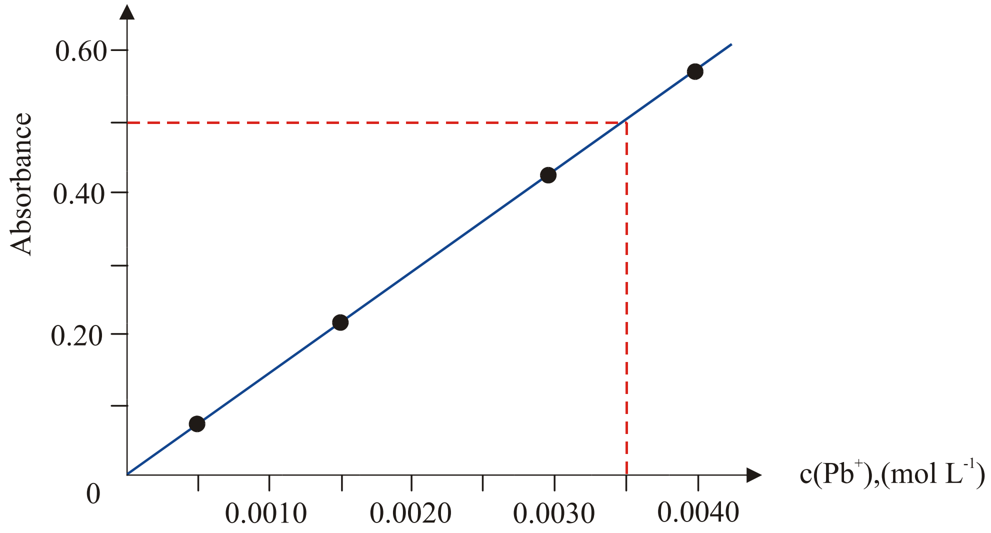
c. Not washing the precipitate with water will leave any soluble impurities trapped and lead to a higher than true mass *m*($BaSO_4$). ❶ This will lead to a lower calculated *m*(MgO), hence a lower *n*(Mg^{2+}) and a lower *c*(Mg^{2+}) in the filtrate solution. ❶

Question 7

a. Since the analysis was for the amount of the metal lead in the bore water an **atomic absorption spectrophotometer** ❶ would be used.

b. Electrons are promoted to higher energy levels. ❶

c. Absorbance 0.50



c(Pb) in diluted sample of bore water = **0.0035 mol L^{-1}** ❶

Since the original bore water sample had been diluted by a factor of 2, from 50 mL to 100 mL, then

c(Pb) in bore water = 2 x 0.0035
= **0.0070 mol L^{-1}** ❶

d. *m*(Pb) in one litre = 0.0070 x 207.2
= 1.45 g
= 1.45x10^3 mg (1.5x10^3 ... 2 sig figures) ❶

End of Suggested Answers