VCE Chemistry   **Unit 3**
SECTION A - [12 marks, 15 minutes]

This section contains 12 multiple choice questions.
For each question choose the response that is correct or best answers the question.
Indicate your answer on the answer sheet provided.
*(Choose only **one** answer for each question.)*

Question 1
When a sample of a hydrocarbon was completely burnt in pure oxygen it produced 2.000 L of carbon dioxide at SLC and 1.836 g of water. The empirical formula for this hydrocarbon is
> A. C_4H_5.
> B. CH_2.
> C. CH.
> D. C_2H_5

Question 2
A gaseous pollutant was isolated from a city's atmosphere. A 2.78 g sample of the gas occupied 2.35 L at 18 °C and 102 kPa. The pollutant is most likely
> A. NO.
> B. CO.
> C. NO_2.
> D. O_3.

Question 3
What volume of 0.100 M aqueous sulfuric acid solution would be required to neutralise a 20.00 mL aliquot of 0.150 M aqueous sodium hydroxide solution?
> A. 15.0 mL.
> B. 30.0 mL.
> C. 60.0 mL.
> D. 20.0 mL.

Question 4
Which one of the following chemical equations would best represent the reduction of chromium(III) ions by zinc metal?
> A. $Cr^{3+}(aq) + Zn(s) \rightarrow Cr^{2+}(aq) + Zn^{+}(aq)$
> B. $Cr^{3+}(aq) + Zn^{2+}(aq) \rightarrow Cr^{2+}(aq) + Zn^{3+}(aq)$
> C. $2Cr^{3+}(aq) + Zn(s) \rightarrow 2Cr^{2+}(aq) + Zn^{2+}(aq)$
> D. $2Cr^{3+}(aq) + Zn^{2+}(aq) \rightarrow 2Cr^{4+}(aq) + Zn$

Question 5
Which one of the following changes will **not** affect the R_f value for thin layer chromatography?
> A. Allowing the solvent to travel a larger distance from then origin on the plate.
> B. Using a different absorbent material on the plate.
> C. Developing the plate using a more polar solvent.
> D. Developing the plate using a less polar solvent.

Question 6

The titration of an aqueous solution of phosphoric acid with an aqueous solution of potassium hydroxide was carried out to an indicator end-point. A 10.00 mL aliquot 0.250 M of phosphoric acid required a titre of 12.50 mL of 0.400 M potassium hydroxide. Which one of the following chemical equations best describes the reaction for this titration?

A. $H^+(aq) + OH^-(aq) \rightleftharpoons H_2O(l)$

B. $H_3PO_4(aq) + 3KOH(aq) \rightarrow K_3PO_4(aq) + 3H_2O(l)$

C. $H_3PO_4(aq) + 2KOH(aq) \rightarrow K_2HPO_4(aq) + 2H_2O(l)$

D. $H_3PO_4(aq) + KOH(aq) \rightarrow KH_2PO_4(aq) + H_2O(l)$

Question 7

In atomic absorptions spectroscopy, AAS, the light that is analysed

A. originates from the light emitted in the flame by the atoms of the element being analysed.

B. originates from a lamp emitting light of a specific wavelength that is absorbed by the atoms of the element being analysed.

C. originates from a white light source that is absorbed by the atoms of the element being analysed.

D. originates from light that is absorbed by the atoms of the element being analysed in the flame.

Question 8

What would be the sulfate ion concentration in a solution prepared by mixing 50.0 mL of 0.100 M sodium sulfate and 25.00 mL of 0.250 M aluminium sulfate solutions?

A. 0.150 M

B. 0.233 M

C. 0.317 M

D. 0.467 M

Question 9

When calcium carbonate is heated it decomposes according to the chemical equation,

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$
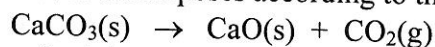
A 1.839 g sample of a mixture of calcium carbonate and calcium oxide was heated and a mass loss of 0.572 g was recorded. What was the percentage by mass (% w/w) of calcium oxide in the original sample?

A. 70.7 %

B. 31.1 %

C. 68.9 %

D. 29.3 %

Question 10

In a reduction-oxidation reaction

A. the oxidation number of the oxidant decreases by the same amount as the oxidation number of the reductant increases.

B. the oxidation number of the oxidant decreases and the oxidation number of the reductant increases.

C. the oxidation number of the oxidant increases and the oxidation number of the reductant decreases.

D. the oxidation number of the oxidant increases by the same amount as the oxidation number of the reductant decreases.

Question 11

An artist wanted to know if a paint contained copper compounds. Which of the following techniques would be most suited to answering the artist's request?

A. UV-Visible spectrophotometry.
B. Paper chromatography.
C. High performance liquid chromatography (HPLC).
D. Flame test.

Question 12

Which of the following procedures would need to be followed to prepare a 0.100 M aqueous sodium carbonate standard solution?

A. Dissolve 2.650 g of anhydrous sodium carbonate in distilled water so that the total volume of the solution was 250.0 mL
B. Dissolve 2.65 g of sodium carbonate in 250.00 mL of distilled water.
C. Dissolve 7.1500 g of sodium carbonate decahydrate in 250.00 mL of distilled water.
D. Dissolve 7.150 g of sodium carbonate decahydrate in distilled water so that the total volume of the solution was 250.0 mL

End of Section A

SECTION B - [28 marks, 35 minutes]

This section contains four questions, numbered 1 to 4.
All questions should be answered in the spaces provided.
The mark allocation and approximate time that should be spent on each question are given.

**Question 1 - [7 marks, 9 minutes]**

A 12.387 g sample of garnierite, a mineral containing nickel, was analysed for its nickel content by digesting it in concentrated acid and then diluting the resultant solution with distilled water to 200.0 mL in a volumetric flask. A 50.00 mL sample of this solution then had dimethylglyoxime reagent added to it to precipitate the compound $Ni(C_4H_7O_2N_2)_2$. The precipitate was thoroughly washed with water and dried at 110 °C to constant mass. The mass of dried precipitate was found to be 2.869 g.

a. Calculate the mass of nickel in the 50.00 mL sample used to obtain the precipitate.

2 marks

b. Calculate the percentage by mass (% w/w) of nickel in the mineral sample.

2 marks

c. Give one reason why it is a better procedure to dry the precipitate to constant mass, rather than to dry it for a specific time.

1 mark

d. When a sample of the precipitate was dried at a much higher temperature, the calculated nickel content was lower than when the above procedure was followed. Give one possible explanation for this observation.

1 mark

e. What instrumental analytical technique could be used in place of the above gravimetric procedure?

1 mark

Question 2 - [9 marks, 11 minutes]

Potassium iodate, KIO_3, is often used as a primary standard for titrations that require iodine, as it will react with excess iodide ions in weakly acidic solutions to form iodine in solution as described by the chemical equation,

$$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$$
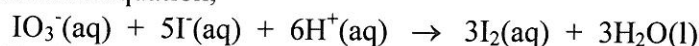
a.   A solution of iodine was prepared by adding excess potassium iodide to 2.500 mL of 2.000×10^{-3} M potassium iodate solution.

   Calculate the number of mole of iodine that would be formed in this solution.

2 marks

b.   An aqueous solution of sodium thiosulfate, $Na_2S_2O_3$, was standardised using this solution. The chemical equation for this reaction is

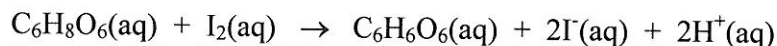$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$
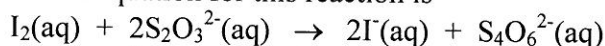
   The solution formed in a. above required 10.53 mL of sodium thiosulfate solution.

   i. Calculate the number of mole of thiosulfate that reacted with the iodine.

   ii.   Calculate the concentration of the sodium thiosulfate solution.

$2 \times 1 = 2$ marks

c.   Vitamin C, ascorbic acid, $C_6H_8O_6$, is oxidised by iodine as described by the chemical equation,

$$C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2I^-(aq) + 2H^+(aq)$$

   A 2.500 mL sample of a fruit drink was allowed to react with the solution formed in a. above, and the excess iodine was then titrated with the sodium thiosulfate solution standardised in b. above. The titration required 7.514 mL of sodium thiosulfate solution.

   i. Calculate the number of mole of thiosulfate added in the titration.

   ii.   Calculate the number of mole of iodine that was in excess after the reaction with the vitamin C.

iii. Calculate the number of mole of iodine that reacted with the vitamin C.

iv. Calculate the mass in milligram, mg, of vitamin C in the sample

v. Express the concentration of vitamin C in the fruit drink in mg/100 mL.

$5 \times 1 = 5$ marks

Question 3 - [5 marks, 6 minutes]

a. Draw a labelled diagram to show the key components in a high performance liquid chromatograph, HPLC.

2 marks

b. Give one example for the use of HPLC as an analytical tool.

1 mark

c. The diagrams below show the high performance liquid chromatograms for a mixture containing equal amounts of [A] ethanol, C_2H_5OH, [B] propanol, C_3H_7OH and [C] glycerol, $CH_2(OH)CH(OH)CH_2(OH)$, obtained from three different instruments.
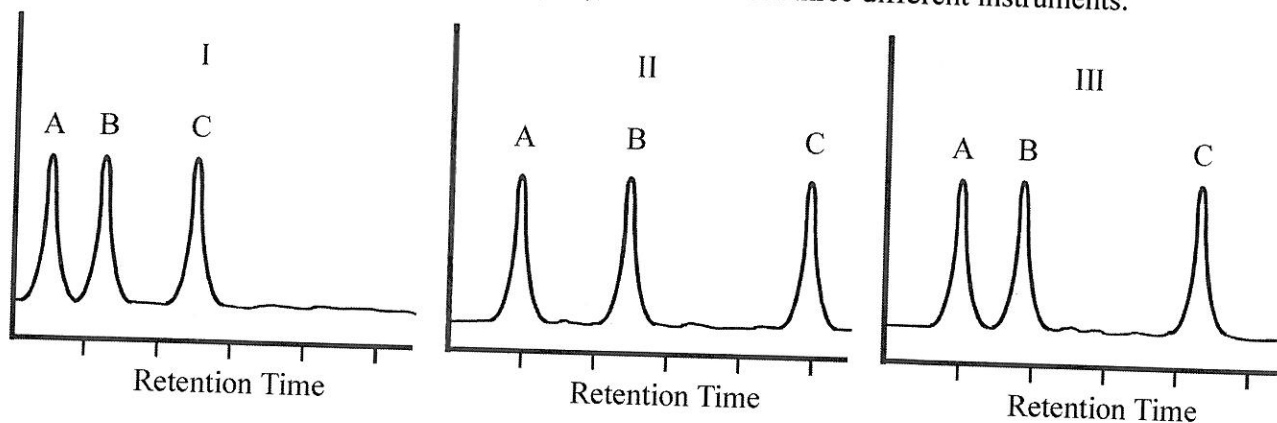
i. What would be one factor that could explain the difference between chromatogram I and II?

ii. What would be one factor that could explain the difference between chromatogram I and III?

**Question 4** - [7 marks, 9 minutes] $2 \times 1 = 2$ marks

A chemist analysing soft drinks used a spectrophotometric technique to determine their phosphate ion, PO_4^{3-}(aq), content. A suitable reagent was added to standard solutions and the absorbances measured using red light with a wavelength of 830 nm. The data for the absorbances of the standard solutions are contained in the table below.

Concentration (ppm PO_4^{3-}(aq))	Absorbance
2.0	0.26
4.0	0.51
6.0	0.77
8.0	1.02
10.0	1.27

a. What is the colour of the material in solution being analysed?

1 mark

b.   On the grid below construct the calibration curve from the above data.
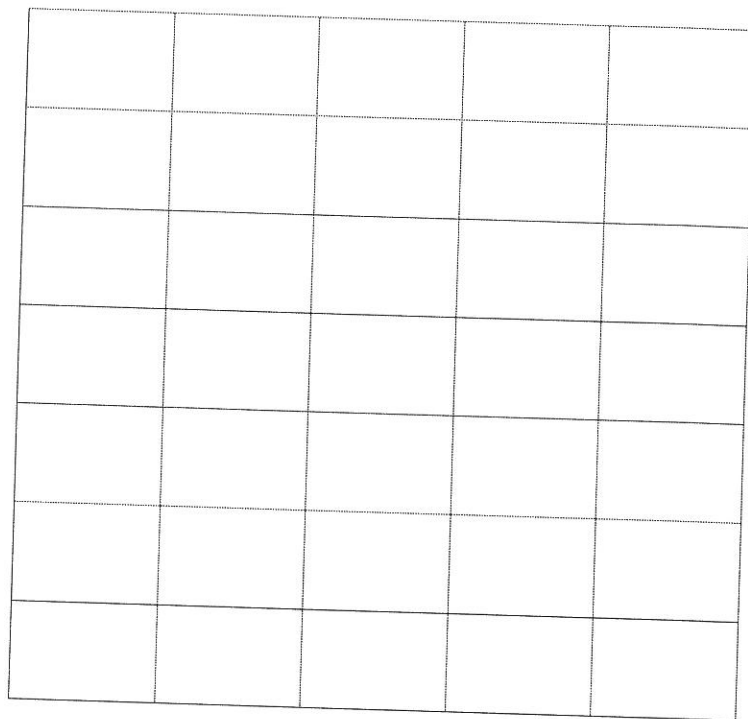
2 marks

c.   A sample of soft drink was allowed to degas over a 24 hour period. A 5.00 mL sample
of this was then added to a 100.0 mL volumetric flask and diluted to the mark with
distilled water. 1.00 mL samples of this diluted sample were treated with the reagent
added to the standard solutions and then diluted with distilled water until the total
volume was 5.00 mL. The average absorbance for the samples was 0.56.
Use the calibration curve to determine:
i.   The concentration of phosphate ions in the measured sample.

ii.   The concentration of phosphate ions in the original soft drink.

iii.   The mass of phosphate ions that would need to be printed on the information
panel for a 375 mL can of soft drink.

1 + 2 + 1 = 4 marks
End of task

Suggested Answers VCE Chemistry 2005 Analytical Test Unit 3
SECTION A [1 mark per question.]

Q1 D The formula for the hydrocarbon can be written as C_xH_y and the combustion reaction can be written as,

$C_xH_y(g) + (x + \frac{y}{4})O_2(g) \rightarrow xCO_2(g) + (\frac{y}{2})H_2O(l)$

Therefore using the molar ratio of carbon dioxide and water

$n(CO_2) = V / V_M = 2.000/24.5 = 0.0816$ mol (Gas at SLC)

$n(H_2O) = m / M = 1.836/18.0 = 0.102$ mol

$x : y = n(CO_2) : 2n(H_2O) = 0.0816 : 2 \times 0.102 = 0.0816 : 0.204$ (divide both by smaller)

$x : y = 1 : 2.5 \Rightarrow 2 : 5$ **C_2H_5**

Q2 B Using the general gas equation since the conditions are not SLC or STP.

$PV = nRT \Rightarrow n = \dfrac{PV}{RT} = \dfrac{102.0 \times 2.35}{8.31 \times (18 + 273)} = 0.0991$ mol

$M = m / n = 2.78 / 0.0991 = 28.0$ g mol^{-1}

$M(CO) = 12.0 + 16.0 = 28.0$ g mol$^{-1} \Rightarrow$ **CO**

Q3 A The chemical equation for the neutralisation of sulfuric acid by sodium hydroxide is, (remember sulfuric acid is a diprotic acid),

$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

$n(NaOH) = c \times V = 0.150 \times (20.00/1000) = 3.00 \times 10^{-3}$ mol (volume in L)

$n(H_2SO_4) = \frac{1}{2}n(NaOH) = \frac{1}{2} \times 3.00 \times 10^{-3} = 1.50 \times 10^{-3}$ mol

$v(H_2SO_4) = n / C = 1.50 \times 10^{-3} / 0.100 = 1.50 \times 10^{-2}$ L = **15.0 mL**

Q4 C The chromium(III) ion is being reduced therefore must go to a lower oxidation number, chromium(II), Cr^{2+}. The half-equation for this reduction therefore is

$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$

The oxidation of zinc, from the electrochemical series on the data sheet,

$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

Balancing the number of electrons produced and consumed in the two half-equations before adding them, gives the overall ionic equation

$2Cr^{3+}(aq) + Zn(s) \rightarrow 2Cr^{2+}(aq) + Zn^{2+}(aq)$

Q5 A The R_f value is determined by the ratio of distance travelled by the material to the distance travelled by the solvent. Increasing the distance travelled by the solvent will also increase the distance travelled by the material, and therefore not change the R_f value. Changing the absorbent or stationary phase could change the R_f value, as the material could be adsorbed more or less strongly than previously. Using a more polar solvent to develop the plate will result in better desorption of polar materials and poorer desorption of non-polar materials thereby changing the R_f value.

Better desorption of the material into the mobile phase will increase the R_f value, while poorer desorption will decrease the R_f Value.

Q6 C The chemical equation for the titration can be determined by the molar ratio.

$n(H_3PO_4) = c \times V = 0.250 \times (10.00/1000) = 2.50 \times 10^{-3}$ mol

$n(KOH) = c \times V = 0.400 \times (12.50/1000) = 5.0 \times 10^{-3}$ mol

$n(H_3PO_4) : n(KOH) = 2.50 \times 10^{-3} : 5.00 \times 10^{-3} = 1 : 2$, therefore

$H_3PO_4(aq) + 2KOH(aq) \rightarrow K_2HPO_4(aq) + 2H_2O(l)$

Q7 B The light that is analysed comes from a lamp emitting light of a specific wavelength which passes through the flame where the atoms present absorb some of the light. The absorbance is determined by the concentration of the atoms.

Q8 C Sodium sulfate: $Na_2SO_4(s) \rightarrow 2Na^+(aq) + SO_4^{2-}(aq)$
Aluminium sulfate: $Al_2(SO_4)_3(s) \rightarrow 2Al^{3+}(aq) + 3SO_4^{2-}(aq)$
$n(Na_2SO_4) = c \times V = 0.100 \times (50.00/1000) = 5.00 \times 10^{-3}$ mol
thus from Na_2SO_4: $n(SO_4^{2-}) = n(Na_2SO_4) = 5.00 \times 10^{-3}$ mol
$n(Al_2(SO_4)_3) = c \times V = 0.250 \times (25.00/1000) = 6.25 \times 10^{-3}$ mol
thus from $Al_2(SO_4)_3$: $n(SO_4^{2-}) = 3n(Al_2(SO_4)_3) = 3 \times 6.25 \times 10^{-3} = 1.88 \times 10^{-2}$ mol
The total sulfate ion: $n(SO_4^{2-}) = 5.00 \times 10^{-3} + 1.88 \times 10^{-2} = 2.38 \times 10^{-3}$ mol
The total volume of the solution formed = 50.00 + 25.00 = 75.00 ml
$c(SO_4^{2-}) = n / V = 2.38 \times 10^{-2} / (75.00/1000) = $ **0.317 M**

Q9 D The mass loss is due to the carbon dioxide evolved in the decomposition reaction.
$n(CO_2) = m / M = 0.572 / (12.0 + 2 \times 16.0) = 1.30 \times 10^{-2}$ mol
$n(CaCO_3) = n(CO_2) = 1.30 \times 10^{-2}$ mol
$m(CaCO_3) = n \times M = 1.30 \times 10^{-2} \times (40.1 + 12.0 + 3 \times 16.0) = 1.301$ g
$m(CaO) = $ mass sample $- m(CaCO_3) = 1.839 - 1.301 = 0.538$ g
$\%(CaO) = (0.538/1.839) \times (100/1) = $ **29.3 %**

Q10 B In a reduction-oxidation (redox) reaction the oxidant causes oxidation and is itself reduced while the reductant causes reduction and is itself oxidised. Therefore the oxidation number for the oxidant decreases as it is reduced and the oxidation number for the reductant increases as it is oxidised.
While the overall number of electrons produced and consumed in a redox reaction is the same the changes in the oxidation numbers for the oxidant and reductant can be the same or different depending on the substances. (This is why response A is not the best answer.)
Examples: $Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$
$2Ag^+(aq) + Zn(s) \rightarrow 2Ag(s) + Zn^{2+}(aq)$

Q11 D The artist only wants to know if the paint contains copper compounds or not, therefore only a qualitative test needs to be carried out. Copper compounds give a characteristic blue-green flame test, and this can be analysed spectroscopically to confirm copper.

Q12 A To prepare a standard solution the exact composition of the solute must be known and the exact volume of the solution (solvent plus solute) measured. Sodium carbonate decahydrate would not be a suitable compound as this material is efflorescent, can lose water from its structure, therefore the exact number of mole of material weighed out is not known, and hence the concentration would not be accurately known.

SECTION B
Question 1 - [7 marks, 9 minutes]
a. $M(Ni(C_4H_7O_2N_2)_2) = 58.7 + 2 \times (4 \times 12.0 + 7 \times 1.0 + 2 \times 16.0 + 2 \times 14.0) = 288.7$ g mol^{-1}
From the 50.00 mL sample 2.869 g of precipitate was obtained:
$n(Ni(C_4H_7O_2N_2)_2) = m/M = 2.869/288.7 = 9.937 \times 10^{-3}$ mol
$n(Ni) = n(Ni(C_4H_7O_2N_2)_2) = 9.937 \times 10^{-3}$ mol **[1 mark]**
$m(Ni) = n \times M = 9.937 \times 10^{-3} \times 58.7 = $ **0.583 g [1 mark]**

b.   The original mineral sample was diluted to 200.0 mL from which the 50.00 mL was taken.

$m(Ni,$ in mineral sample$) = 0.583 \times (200.0/50.00) = 2.334$ g **[1 mark]**
$\%(Ni) = (2.334/12.387) \times (100/1) = $ **18.84 % [1 mark]**

c.   Drying for a specific time may not necessarily result in complete dryness of the precipitate, unless this was for a significant time such as 24 hours. Drying to constant mass ensures that all the water has been removed from the solid. **[1 mark]**

d.   As the nickel content is lower this indicates that the mass of the precipitate was lower. Therefore drying the precipitate at a higher temperature may have resulted in the decomposition of the precipitate so that it no longer had the chemical formula, $Ni(C_4H_7O_2N_2)_2$. **[1 mark]**

e.   Either of two answers would be acceptable: **[Total marks allocated: 1 mark]**
     Atomic absorption spectrophotometry (AAS), or
     UV-Visible spectrophotometry (colorimetry).

Question 2 - [9 marks, 11 minutes]

a. $n(IO_3^-) = c \times V = 2.000 \times 10^{-3} \times (2.500/1000) = 5.000 \times 10^{-6}$ mol **[1 mark]**
     $n(I_2) = 3n(IO_3^-) = 3 \times 5.000 \times 10^{-6} M = \mathbf{1.500 \times 10^{-5}}$ **mol [1 mark]**

b.   i. $n(S_2O_3^{2-}) = 2n(I_2) = 2 \times 1.500 \times 10^{-5} M = \mathbf{3.000 \times 10^{-5}}$ **mol [1 mark]**
     ii. $c(S_2O_3^{2-}) = n / V = 3.000 \times 10^{-3} / (10.53/1000) = \mathbf{2.849 \times 10^{-3}}$ **M [1 mark]**

c.   i. $n(S_2O_3^{2-}) = c \times V = 2.849 \times 10^{-3} \times (7.514/1000) = \mathbf{2.141 \times 10^{-5}}$ **mol [1 mark]**
     ii. $n(I_2, \text{excess}) = \frac{1}{2}n(S_2O_3^{2-}) = \frac{1}{2} \times 2.141 \times 10^{-5} = \mathbf{1.070 \times 10^{-5}}$ **mol [1 mark]**
     iii. $n(I_2, \text{reacted}) = 1.500 \times 10^{-5} - 1.070 \times 10^{-5} = \mathbf{4.296 \times 10^{-6}}$ **mol [1 mark]**
     iv. $n(C_6H_8O_6) = n(I_2, \text{reacted}) = 4.296 \times 10^{-6}$ mol
           $M(C_6H_8O_6) = 6 \times 12.0 + 8 \times 1.0 + 6 \times 16.0 = 176$ g mol^{-1}
           $m(C_6H_8O_6) = n \times M = 4.296 \times 10^{-6} \times 176 = 7.561 \times 10^{-4}$ g = **0.756 mg [1 mark]**
     v.   The volume of the fruit juice sample was 2.500 mL
           $m(C_6H_8O_6, \text{in } 100 \text{ mL}) = 0.756 (100/2.500) = \mathbf{30.2}$ **mg/100 mL [1 mark]**
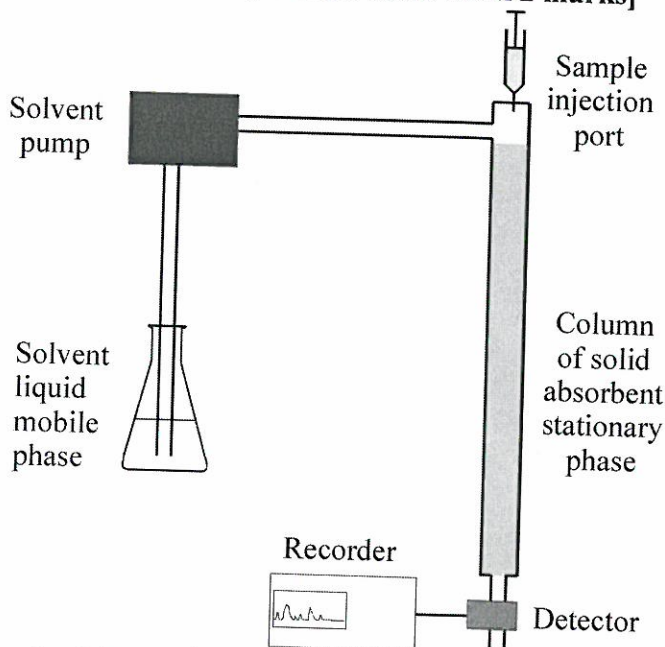
Question 3 - [5 marks, 6 minutes]

a.   The key components that need to be shown are: **[½ mark each. Total 2 marks]**
     Solvent pump
     Sample injection port
     Column
     Detector/recorder

b.   There are many possible answers for this question some possible examples include: **[1 mark]**
   Analysis of urine for steroids or other drugs.
     Analysis of liquid fuels for their hydrocarbon mixtures.
     Analysis of cooking oils for their fatty acid composition.

c. i. The retention times for all three components have roughly doubled therefore the this could be due to either a **slower rate of solvent (mobile phase) flow** or a **longer column (stationary phase) length. [1 mark]**

   ii. The material with the longest retention time in I has a much increased retention time, this could be due to a change in the polarity of either the **absorbent (stationary phase) material** or the **solvent (mobile phase). [1 mark]**

Question 4 - [7 marks, 9 minutes]

a. As the absorbance is being is being measured using red light the material being analysed will be of a complementary colour, namely **blue. [1 mark]**

b. Accurate plotting and labelling of axes. **[Total mark allocation: 2 marks]**
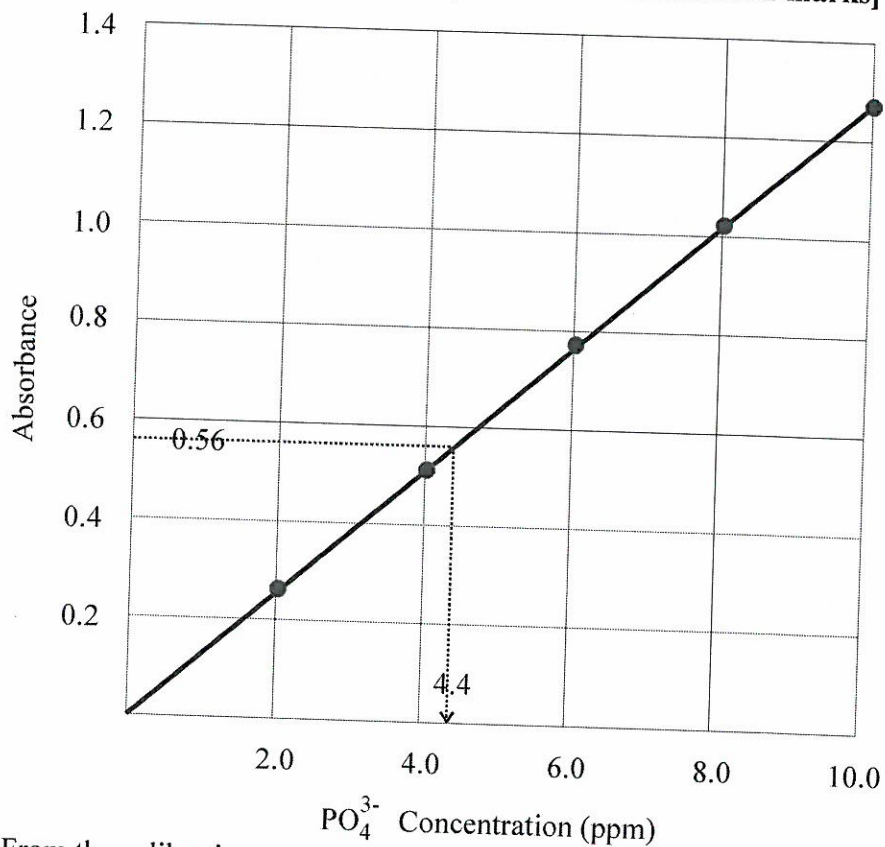
c. i. From the calibration curve an absorbance of 0.56 corresponds to a phosphate ion concentration of **4.4 ppm. [1 mark]**

   ii. The measured sample had a total volume of 5.00 mL originated from 1.00 mL of the diluted soft drink solution. This is a 1 in 5 dilution of the diluted soft drink solution.

   $c(PO_4^{3-}$, in diluted soft drink solution) $= 4.4 \times (5.00/1.00) = 22$ ppm **[1 mark]**

   The diluted soft drink solution was prepared by diluting 5.00 mL of soft drink to 100.0 mL.

   $c(PO_4^{3-}$, in soft drink) $= 22 \times (100.0/5.00) = $ **440 ppm [1 mark]**

   iii. The phosphate concentration is 440 ppm $= 440$ mg L^{-1}

   Therefore the mass of phosphate in 375 mL

   $m(PO_4^{3-}, 375$ mL) $= 440 \times (375/1000) = $ **170 mg [1 mark]**