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,

$C_xH_y(g) + (x + {}^y/_4)O_2(g) \rightarrow xCO_2(g) + ({}^y/_2)H_2O(l)$

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

$x : y = n(CO_2) : 2n(H_2O) = 0.0816 : 2\times0.102 = 0.0816 : 0.204$ (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.

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

$M = m / n = 2.78 / 0.0991 = 28.0$ 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),

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

$n(NaOH) = c \times V = 0.150 \times (20.00/1000) = 3.00\times10^{-3}$ mol (volume in L)

$n(H_2SO_4) = \frac{1}{2}n(NaOH) = \frac{1}{2} \times 3.00\times10^{-3} = 1.50\times10^{-3}$ mol

$v(H_2SO_4) = n / C = 1.50\times10^{-3} / 0.100 = 1.50\times10^{-2}$ 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.

$n(H_3PO_4) = c \times V = 0.250 \times (10.00/1000) = 2.50\times10^{-3}$ mol

$n(KOH) = c \times V = 0.400 \times (12.50/1000) = 5.0\times10^{-3}$ mol

$n(H_3PO_4) : n(KOH) = 2.50\times10^{-3} : 5.00\times10^{-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
$c(SO_4^{2-}) = n / V = 2.38 \times 10^{-2} / (75.00/1000) = \mathbf{0.317\ M}$

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
$\%(CaO) = (0.538/1.839) \times (100/1) = \mathbf{29.3\ \%}$

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]**
$m(Ni) = n \times M = 9.937 \times 10^{-3} \times 58.7 = \mathbf{0.583\ g}$ **[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]**
$\%(Ni) = (2.334/12.387) \times (100/1) = \mathbf{18.84\ \%}$ **[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 = **1.500×10^{-5} mol [1 mark]**

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

c. i. $n(S_2O_3^{2-}) = c \times V = 2.849 \times 10^{-3} \times (7.514/1000) = $ **2.141×10^{-5} mol [1 mark]**
   ii. $n(I_2, excess) = \frac{1}{2}n(S_2O_3^{2-}) = \frac{1}{2} \times 2.141 \times 10^{-5} = $ **1.070×10^{-5} mol [1 mark]**
   iii. $n(I_2, reacted) = 1.500 \times 10^{-5} - 1.070 \times 10^{-5} = $ **4.296×10^{-6} mol [1 mark]**
   iv. $n(C_6H_8O_6) = n(I_2, reacted) = 4.296 \times 10^{-6}$ 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, in 100 mL) = 0.756 (100/2.500) = $ **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
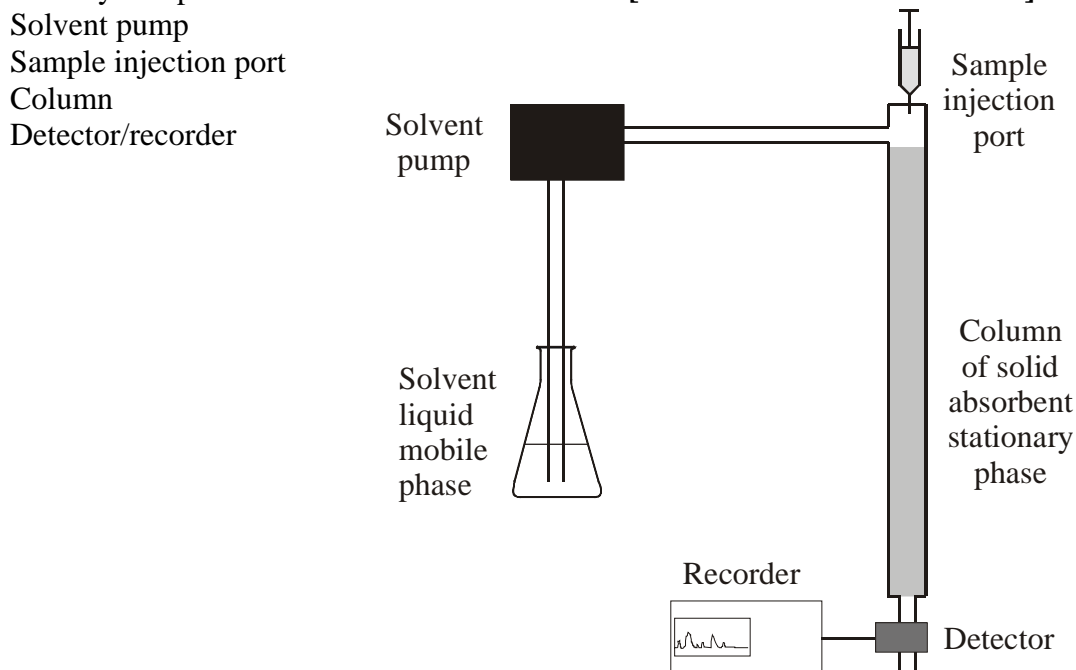
b. There are many possible answers for this question some possible examples include: **[1 mark]**
   Analysis of urine for steroids or other drugs.
   Analysis of liquid fuels for their hydrocarbon mixtures.
   Analysis of cooking oils for their fatty acid composition.

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]**
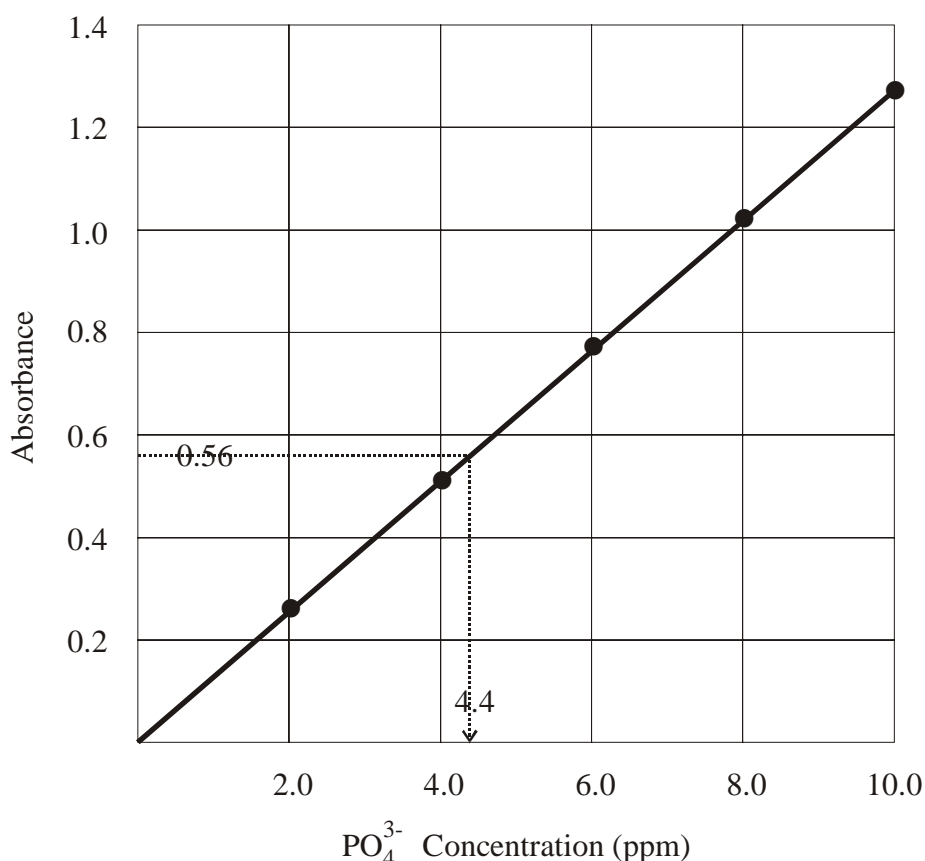
c. i. From the calibration curve an absorbance of 0.56 corresponds to a phosphate ion concentration of **4.4 ppm**. **[1 mark]**

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]**