Chemistry   Physics   Biology
Psychology

VCE CHEMISTRY 2007 ANALYTICAL TEST UNIT 3

Time allowed: 50 minutes
Total marks: 40

SECTION A
Contains 12 multiple choice questions

SECTION B
4 Extended response questions

A data sheet and multiple choice answer sheet are provided. Answer extended response questions in the space provided. Use the marks and time allowed as a guide to how much time you should spend answering each question.

relative atomic number																		2
symbol							1											He
name							H											Helium
relative atomic mass							Hydrogen											4.0
							1.0											

3	4											5	6	7	8	9	10
Li	Be											B	C	N	O	F	Ne
Lithium	Beryllium											Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon
6.9	9.0											10.8	12.0	14.0	16.0	19.0	20.2
11	12											13	14	15	16	17	18
Na	Mg											Al	Si	P	S	Cl	Ar
Sodium	Magnesium											Aluminium	Silicon	Phosphorus	Sulfur	Chlorine	Argon
23.0	24.3											27.0	28.1	31.0	32.1	35.5	39.9
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Potassium	Calcium	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc	Gallium	Germanium	Arsenic	Selenium	Bromine	Krypton
39.1	40.1	44.9	47.9	50.9	52.0	54.9	55.9	58.9	58.7	63.6	65.4	69.7	72.6	74.9	79.0	79.9	83.8
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Rubidium	Strontium	Yttrium	Zirconium	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tellurium	Iodine	Xenon
85.5	87.6	88.9	91.2	92.9	95.9	98.1	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Caesium	Barium	Lanthanum	Hafnium	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon
132.9	137.3	138.9	178.5	180.9	183.8	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	(209)	(210)	(222)
87	88	89	104	105	106	107	108	109	110	111	112		114				
Fr	Ra	Ac	Rf	Ha	Sg	Ns	Hs	Mt	Ds	Rg	Uub		Uuq				
Francium	Radium	Actinium	Rutherfordium	Hahnium	Seaborgium	Neilsbohrium	Hassium	Meitnerium	Darmstadtium	Roentgenium	Ununbium		Ununquadium				
(223)	(226)	(227)	(261)	(262)	(266)	(264)	(269)	(268)	(272)	(272)	(277)		(289)				

Lanthanide series

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium
140.1	140.9	144.2	(145)	150.3	152.0	157.2	158.9	162.5	164.9	167.3	168.9	173.0	175.0

Actinide series

90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium
232.0	231.0	238.0	237.1	(244)	(243)	(247)	(247)	(251)	(254)	(257)	(258)	(255)	(256)

DATA SHEET

Physical Constants

F = 96 500 C mol^{-1}

R = 8.31 JK^{-1} mol^{-1}

V$_m$ (STP) = 22.4 L mol^{-1}

V$_m$ (SLC) = 24.5 L mol^{-1}

Specific heat of water = 4.184 J mL^{-1} $^\circ$C^{-1}

Ideal gas equation

$$pV = nRT$$

The Electrochemical Series

E° in volt

$F_2(g) + 2e^-$	$\rightarrow 2F^-(aq)$	+ 2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^-$	$\rightarrow 2H_2O(l)$	+ 1.77
$Au^+(aq) + e^-$	$\rightarrow Au(s)$	+ 1.68
$MnO_4^-(aq) + 8H^+(aq) + 5e^-$	$\rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+ 1.50
$Cl_2(g) + 2e^-$	$\rightarrow 2Cl^-(aq)$	+ 1.36
$O_2(g) + 4H^+(aq) + 4e^-$	$\rightarrow 2H_2O(l)$	+ 1.23
$Br_2(l) + 2e^-$	$\rightarrow 2Br^-(aq)$	+ 1.09
$Ag^+(aq) + e^-$	$\rightarrow Ag(s)$	+ 0.80
$Fe^{3+}(aq) + e^-$	$\rightarrow Fe^{2+}(aq)$	+ 0.77
$I_2(s) + 2e^-$	$\rightarrow 2I^-(aq)$	+ 0.54
$O_2(g) + 2H_2O(l) + 4e^-$	$\rightarrow 4OH^-(aq)$	+ 0.40
$Cu^{2+}(aq) + 2e^-$	$\rightarrow Cu(s)$	+ 0.34
$CO_2(g) + 8H^+(aq) + 8e^-$	$\rightarrow CH_4(g) + 2H_2O(l)$	+ 0.17
$S(s) + 2H^+(aq) + 2e^-$	$\rightarrow H_2S(g)$	+ 0.14
$2H^+(aq) + 2e^-$	$\rightarrow H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^-$	$\rightarrow Pb(s)$	- 0.13
$Sn^{2+}(aq) + 2e^-$	$\rightarrow Sn(s)$	- 0.14
$Ni^{2+}(aq) + 2e^-$	$\rightarrow Ni(s)$	- 0.23
$Co^{2+}(aq) + 2e^-$	$\rightarrow Co(s)$	- 0.28
$Fe^{2+}(aq) + 2e^-$	$\rightarrow Fe(s)$	- 0.44
$Zn^{2+}(aq) + 2e^-$	$\rightarrow Zn(s)$	- 0.76
$2H_2O(l) + 2e^-$	$\rightarrow H_2(g) + 2OH^-(aq)$	- 0.83
$Mn^{2+}(aq) + 2e^-$	$\rightarrow Mn(s)$	- 1.03
$Al^{3+}(aq) + 3e^-$	$\rightarrow Al(s)$	- 1.67
$Mg^{2+}(aq) + 2e^-$	$\rightarrow Mg(s)$	- 2.34
$Na^+(aq) + e^-$	$\rightarrow Na(s)$	- 2.71
$Ca^{2+}(aq) + 2e^-$	$\rightarrow Ca(s)$	- 2.87
$K^+(aq) + e^-$	$\rightarrow K(s)$	- 2.93
$Li^+(aq) + e$	$\rightarrow Li(s)$	- 3.02

Student Name……………………………….

VCE Chemistry 2007 Analytical Chemistry Test Unit 3

SECTION A

MULTIPLE CHOICE ANSWER SHEET

Instructions:
> For each question choose the response that is correct or best answers the question.
> Circle the chosen response on this answer sheet.
> Only circle **one** response for each question.

Question 1.	A	B	C	D
Question 2.	A	B	C	D
Question 3.	A	B	C	D
Question 4.	A	B	C	D
Question 5.	A	B	C	D
Question 6.	A	B	C	D
Question 7.	A	B	C	D
Question 8.	A	B	C	D
Question 9.	A	B	C	D
Question 10.	A	B	C	D
Question 11.	A	B	C	D
Question 12.	A	B	C	D

VCE Chemistry 2007 Analytical Test Unit 3

SECTION A - [12 marks, 15 minutes]
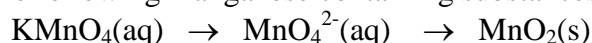
This section contains 12 multiple choice questions.
For each question choose the response that is correct or best answers the question.
Indicate your answer on the answer sheet provided.
*(Choose only **one** answer for each question.)*

Question 1
In a reaction sequence the following manganese containing substances were identified;
$$KMnO_4(aq) \rightarrow MnO_4^{2-}(aq) \rightarrow MnO_2(s)$$
What are the respective formal oxidation states for manganese in this reaction sequence?
- A. +8, +6, +2.
- B. +8, +8, +2.
- C. +7, +8, +4.
- D. +7, +6, +4.

Question 2
A student carried out an acid-base titration, by titrating aliquots of base with an acid of stated concentration. Which one of the following would result in the student calculating a higher than expected concentration of the base from the results obtained?
- A. The pipette was rinsed with deionised water after each aliquot of base was pipetted into the conical flask.
- B. The concentration of the acid used was actually lower than that stated.
- C. The indicator used had an end point at a higher pH than that of the equivalence point.
- D. The concentration of the acid was actually higher than that stated.

Question 3
Which one of the following changes will increase the R_f value for a polar compound?
- A. Use a more polar absorbent.
- B. Use a more polar solvent.
- C. Use a less polar solvent.
- D. Use a longer chromatogram.

Questions 4 & 5 refer to the following information.
A 1.170 g sample of a hydrocarbon occupied a volume of 470 mL at 150 °C and 104 kPa.
When this hydrocarbon sample was completely burnt in oxygen it produced 3.678 g of carbon dioxide and 1.504 g of water.

Question 4
The empirical formula for the hydrocarbon is
- A. C_2H.
- B. CH_3.
- C. CH.
- D. CH_2.

Question 5
The molecular formula for the hydrocarbon is
- A. C_6H_{12}.
- B. C_6H_6.
- C. C_8H_8.
- D. C_8H_{16}.

Questions 6 & 7 refer to the following information.
A spectrophotometric method for analysing samples containing methanol, CH_3OH, uses an acidic solution of potassium dichromate to oxidise the methanol to methanoic acid, HCOOH. Standard solutions of methanol were prepared and 1.00 mL aliquots of these were added to 9.00 mL aliquots of the acidic dichromate solution. The absorbances of the resultant solutions were measured and the graph below shows these results.

Concentration of Methanol in Standard Solutions
[**M**]
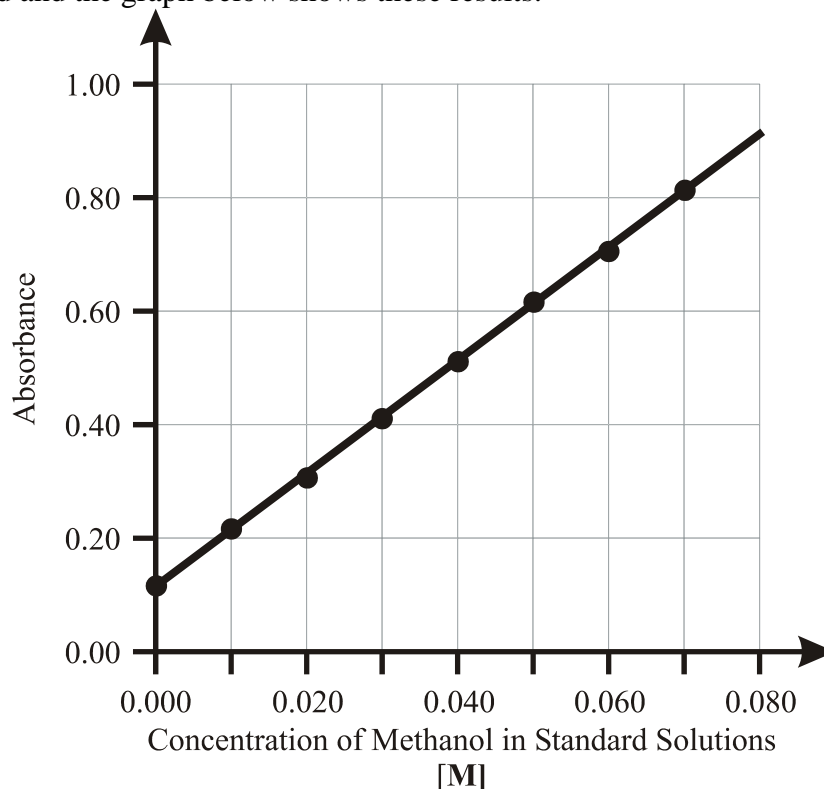
Question 6
The chemical half-equation for the oxidation of methanol by the acidic dichromate solution is
- A. $CH_3OH(aq) + H_2O(l) \rightarrow HCOOH(aq) + 4H^+(aq) + 4e^-$.
- B. $CH_3OH(aq) + H_2O(l) + 4e^- \rightarrow HCOOH(aq) + 4H^+(aq)$.
- C. $CH_3OH(aq) + H_2O(l) \rightarrow HCOOH(aq) + 2H^+(aq) + 2e^-$.
- D. $3CH_3OH(aq) + 2Cr_2O_7^{2-}(aq) + 16H^+(aq) \rightarrow 3HCOOH(aq) + 4Cr^{3+}(aq) + 11H_2O(l)$.

Question 7

A 20.00 mL sample of the original methanol containing solution was placed in a 250.0 mL volumetric flask and diluted with deionised water to the mark. When a 1.00 mL sample of this solution was treated in a similar way to the standard methanol solutions, an absorbance of 0.47 was obtained.

What is the concentration of methanol in the original solution?

    A.   0.35 M
   B.   0.035 M
    C.   0.44 M
    D.   0.0028 M

Question 8

Which one of the following would be the least important criterion for the selection of a substance to be used as a primary standard?
    A.   A pure form of the substance is readily available.
    B.   The substance has a known chemical formula.
    C.   The substance is inexpensive to purchase in large quantities.
    D.   The substance does not deteriorate with storage or react with the atmosphere.

Question 9

Sodium hydrogen carbonate, $NaHCO_3$, will decompose to sodium carbonate, Na_2CO_3, when heated. This decomposition reaction can be described by the chemical equation;

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$$
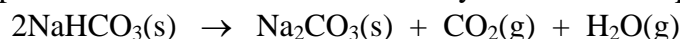
When a 4.081 g sample containing a mixture of both compounds was heated a mass loss of 0.636 g occurred. The percentage by mass of sodium carbonate in the original sample was
    A.   42.2 %.
    B.   40.5 %.
    C.   78.9 %.
    D.   57.8 %.

Question 10

The reaction between aqueous solutions of silver nitrate and barium hydroxide can be represented by the chemical equation;

$$2AgNO_3(aq) + Ba(OH)_2(aq) \rightarrow Ag_2O(s) + H_2O(l) + Ba(NO_3)_2(aq)$$

25.0 mL of 0.100 M silver nitrate solution is mixed with 20.0 mL of 0.0500 M barium hydroxide solution and allowed to react. The mass of silver oxide produced will be
    A.   0.580 g.
    B.   0.290 g.
    C.   0.232 g.
    D.   0.464 g.

Question 11

For which one of the following analytical procedures would a flame test be suitable?
    A.   Determining the amount of strontium present in a mineral sample.
    B.   Determining if a sample contained any sulfate ions.
    C.   Determining the amount of potassium in a salt sample.
    D.   Determining if a soil sample contained a calcium compound.

Question 12

Which one of the following would result in a lower than expected result following a gravimetric analysis procedure?

    A.   Not drying the precipitate to constant mass.

    B.   Adding insufficient precipitating reagent to the original solution.

    C.   Not washing the precipitate sufficiently to remove any impurities.

    D.   Allowing the dried precipitate to absorb moisture from the atmosphere before weighing.

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 - [8 marks, 10 minutes]
When aqueous solutions containing copper(II) and iodide ions are mixed, one of the products produced is iodine.
To investigate this reaction a group of students added 10.0 mL of 0.45 M potassium iodide (in excess) to 10.00 mL aliquots of 0.136 M copper(II) sulfate solution. The resultant mixtures were then titrated with standardised 0.0764 M sodium thiosulfate solution, $Na_2S_2O_3$, which only reacted with the iodine formed in the above reaction, converting it back to iodide ions. The average titre obtained was 17.81 mL.
The thiosulfate ion was oxidised to the dithionate ion, $S_4O_6^{2-}$, when it reacted with the iodine.

a. Write a redox half-equation for the oxidation of the thiosulfate ion to the dithionate ion.

[1 mark]

b. Write the overall chemical equation for the reaction between the iodine and the thiosulfate ions.

[1 mark]

c. Calculate the number of mole of thiosulfate ions added during the titration.

[1 mark]

d. Calculate the number of mole of iodine that reacted with the thiosulfate ions above.

[1 mark]

e. Calculate the number of mole of iodide ions that reacted with the copper(II) ions to form the iodine.

[1 mark]

f. Calculate the number of mole of the number of mole of copper(II) ions initially added.

[1 mark]

g. Calculate the mole ratio of copper(II) to iodide ions that reacted.
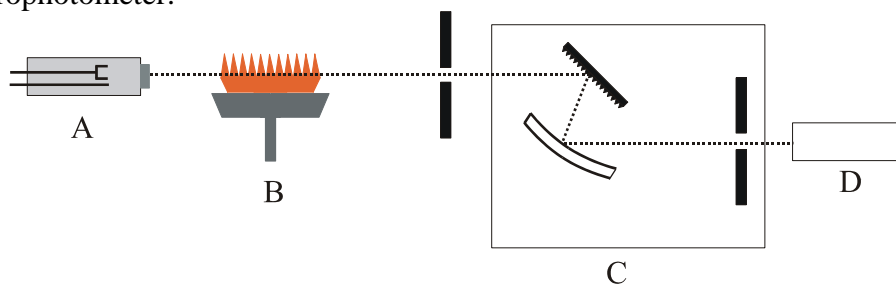
[1 mark]

h. The common oxidation states for copper are; copper, Cu; copper(I), Cu^+; copper(II), Cu^{2+}; and copper(III), Cu^{3+}. Use the above mole ratio to determine the oxidation state for the copper formed in the reaction. Then write the appropriate redox half-equation to represent the reaction that the copper(II) ion underwent in the reaction.

[1 mark]

Question 2 - [11 marks, 14 minutes]

a. The diagram below shows the key components of a basic atomic absorption spectrophotometer.

Identify each of the components labelled A to D and state their role in the spectrophotometer.

i. A.

[1½ **marks**]

ii. B.

[1½ **marks**]

iii. C.

[1½ **marks**]

iv. D.

[1½ **marks**]

b. Over a number of years the amount of lead in soils, particularly in areas where children play, has attracted the attention of the media. The average amount of lead in soils is about 23 ppm but can vary in uncontaminated sites from 2 ppm up to 190 ppm. In preparation for analysing a soil sample for lead a chemist calibrated an atomic absorption spectrophotometer using standardised solutions of lead nitrate. This data is shown in the table below. Use the data below to plot the calibration curve for the spectrophotometer on the grid provided.

Concentration (ppm)	Absorbance
0.0	0.00
4.0	0.75
8.0	1.45
10.0	1.85
12.0	2.20
16.0	2.90
20.0	3.65
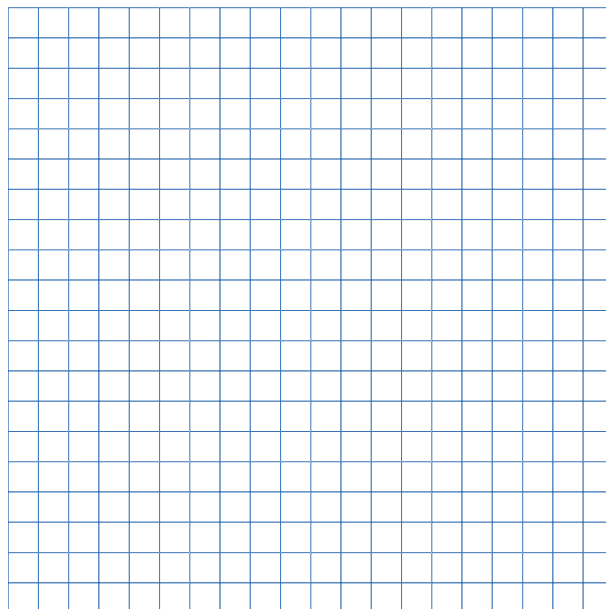
[2 marks]

c. To analyse the soil, the chemist took a 3.852 g sample of soil and reacted it with acid to convert the lead present to water soluble compounds. The sample was filtered and the filtrate and washings were diluted with deionised water in a 100.0 mL volumetric flask. When analysed using the atomic absorption spectrophotometer calibrated in b. above an absorbance of 2.65 was obtained.

i.   What was the concentration of lead in the solution analysed?

[1 mark]

ii. What mass of lead was present in the sample?

[1 mark]

iii. What was the lead content of the soil expressed in ppm (m/m)?

[1 mark]

Question 3 - [5 marks, 6 minutes]
Chlorination of water supplies is an effective method for killing pathogens and treating drinking water supplies. However, other chemical reactions can occur between the chlorine and organic compounds present in the water, and these can produce small quantities of by-products that have toxic properties.

One group of these by-products are the trihalomethanes. *Diagram I,* below represents a gas-liquid chromatogram for equal molar quantities of four known trihalomethane compounds.

A water sample was treated to extract any trihalomethane compounds and the gas-liquid chromatogram, run under the same conditions, for this sample is shown in *Diagram II*.
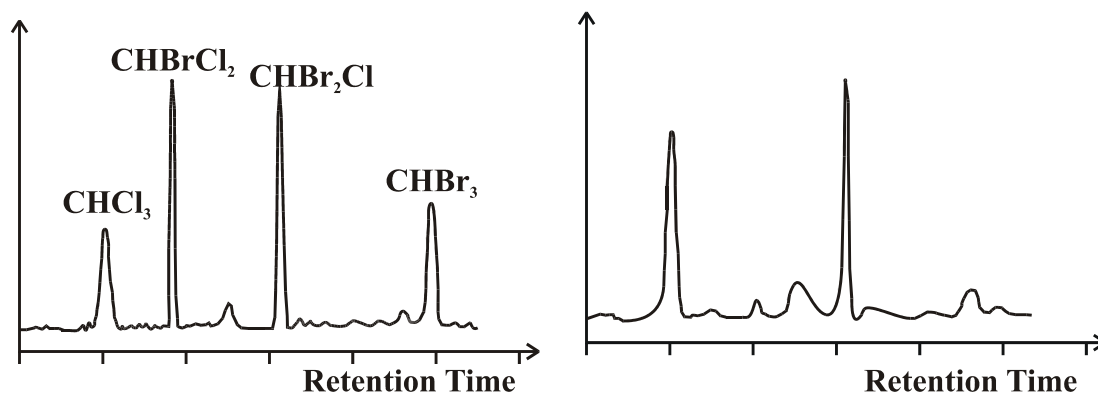
Diagram I   *Diagram II*

a.   Use *Diagram II* to determine the trihalomethane compounds present in the water sample.

[1 mark]

b.   What can be said about the relative amounts of the two main trihalomethane compounds present in the water sample?

[1 mark]

c.   Why is it necessary to obtain the two gas-liquid chromatograms that have been run under the same conditions?

[1 mark]

d.   What are two operational conditions for a gas-liquid chromatograph that can be most readily changed?

[2 marks]

Question 4 - [4 marks, 5 minutes]
The amount of sulfate present in soluble substances can be determined by precipitating the sulfate ions from an aqueous solution by the addition of excess barium ions. This reaction can be described by the chemical equation;

$$SO_4^{2-}(aq) \ + \ Ba^{2+}(aq) \ \rightarrow \ BaSO_4(s)$$
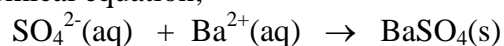
The analytical results for a water soluble sulfate containing fertilizer are shown below.
          Mass of fertilizer sample = 2.279 g
          Mass of filter = 23.291 g
          Mass of filter and dried precipitate = 25.777 g

a.   Calculate the number of mole of barium sulfate in the precipitate.

[2 marks]

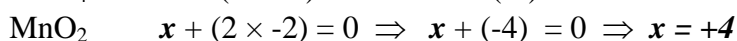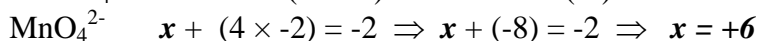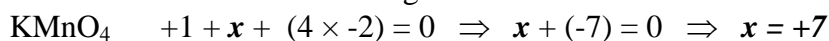b.   Calculate the percentage by mass of sulfate ions in the fertilizer.

[2 marks]

END OF EXAM

Suggested answers VCE chemistry 2007 Analytical Test Unit 3

SECTION A [1 mark per question.]

Q1 D To determine the formal oxidation states for an element in a substance, oxygen is assigned an oxidation state of -2, and main group ions, such as potassium, K^+, there normal oxidation states. The sum of the formal oxidations states for the elements in the substance must be equal to the overall charge on the substance. Let the oxidation state for manganese in each of the substances be equal to x.

$KMnO_4$ $\quad$ $+1 + x + (4 \times -2) = 0 \Rightarrow x + (-7) = 0 \Rightarrow x = +7$

MnO_4^{2-} $\quad$ $x + (4 \times -2) = -2 \Rightarrow x + (-8) = -2 \Rightarrow x = +6$

MnO_2 $\quad$ $x + (2 \times -2) = 0 \Rightarrow x + (-4) = 0 \Rightarrow x = +4$

Q2 B Let the reaction be represented by the chemical equation;

$H^+(aq) + B^-(aq) \rightarrow HB(aq)$ $\qquad$ where $B^-(aq)$ is the base.

Then: $n(H^+) = c(H^+) \times V(H^+)$ $\qquad$ where $V(H^+)$ is the titre volume.

$n(B^-) = n(H^+)$

$c(B^-) = n(B^-) / V(B^-)$ $\qquad$ where $V(B^-)$ is the aliquot volume.

Therefore **if the concentration of the acid used was actually less than that stated**, a **larger volume of acid would be required**, consequently the **calculated concentration of the base would be higher** than expected.

Rinsing the pipette each time with deionised water will dilute the base solution and a lower volume of acid will be required and as a result a lower than expected calculated base concentration.

The initial pH of the base will be high and this will decrease as the acid is added. If the end point occurs at a higher pH then less acid will be required and this will again result in a lower than expected result.

An acid with a concentration higher than that stated will also require less acid to neutralise the base and again result in a lower than expected result.

Q3 B **Polar compounds dissolve more readily in polar solvents**, therefore using a **more polar solvent will result in the compound being desorbed from the stationary phase more readily and moving further from the origin, resulting in a higher R_f value**.

$$R_f = \frac{Dis\tan ce\ compound\ moves\ from\ origin}{Dis\tan ce\ solvent\ moves\ from\ origin}$$

A polar compound will be expected to adsorb more strongly to a more polar absorbent (stationary phase) and this will result in a lower R_f value.

A less polar solvent will result in the compound being less easily eluted and this will result in a lower R_f value.

Using a longer chromatogram will have no effect on the R_f value.

Q4 D In order to determine the empirical formula it is necessary to determine the mole ratio of the two elements present.

$M(CO_2) = 12.0 + 2 \times 16.0 = 44.0$ g mol^{-1}

$M(H_2O) = 2 \times 1.0 + 16.0 = 18.0$ g mol^{-1}

$n(CO_2) = m(CO_2) / M(CO_2) = 3.678 / 44.0 = 8.359 \times 10^{-2}$ mol

$n(C) = n(CO_2) = 8.359 \times 10^{-1}$ mol

$n(H_2O) = m(H_2O) / M(H_2O) = 1.504 / 18.0 = 8.356 \times 10^{-2}$ mol

$n(H) = 2n(H_2O) = 2 \times 8.356 \times 10^{-2} = 1.671 \times 10^{-1}$ mol

$n(C) : n(H) = 8.359 \times 10^{-2} : 1.671 \times 10^{-1} = 1 : 2$

CH_2

Q5 A The empirical formula is CH_2.

The molecular formula is a whole number multiple of the empirical formula, $(CH_2)_x$.
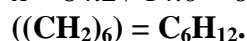
Using the general gas equation $PV = nRT$

$n = \dfrac{PV}{RT}$ $V = 470$ mL $= 470/1000 = 0.470$ L, $T = 150 + 273 = 423$ K

$n((CH_2)_x) = \dfrac{104.0 \times 0.470}{8.31 \times 423} = 1.39 \times 10^{-2}$ mol

$M((CH_2)_x) = m((CH_2)_x) / n((CH_2)_x) = 1.170 / (1.39 \times 10^{-2}) = 84.2$ g mol^{-1}

$M((CH_2)_x) = x \times (12.0 + 2 \times 1.0) = 14.0x = 84.2$

$x = 84.2 / 14.0 = \mathbf{6}$

$\mathbf{((CH_2)_6) = C_6H_{12}.}$

Q6 A The following steps can be used to balance redox half-equations.

1. Identify reactants and products and balance all atoms other than H and O.

    $CH_3OH \longrightarrow HCOOH$

2. Balance oxygen atoms with water molecules.

    Need an extra 1 O atom of left hand side

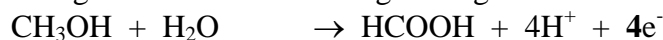 $CH_3OH + H_2O \longrightarrow HCOOH$

3. Balance hydrogen atoms with H$^+$ ions.

    There area a total of 6 H atoms on left and 2 H atoms on the right therefore an extra 4 H$^+$ ions are needed on the right

    $CH_3OH + H_2O \longrightarrow HCOOH + \mathbf{4H^+}$

4. Balance charge by adding electrons.

    Charge on left $= 0$ Charge on right $+4$ therefore needs 4 e$^-$

    $CH_3OH + H_2O \longrightarrow HCOOH + 4H^+ + \mathbf{4e^-}$

5. Add appropriate state symbols.

    $\mathbf{CH_3OH(aq) + H_2O(l) \longrightarrow HCOOH\ (aq) + 4H^+(aq) + 4e^-}$

Response D is the overall chemical equation for the reaction.

Q7 **C** From the calibration curve

Concentration of Methanol in Standard Solutions
[M]
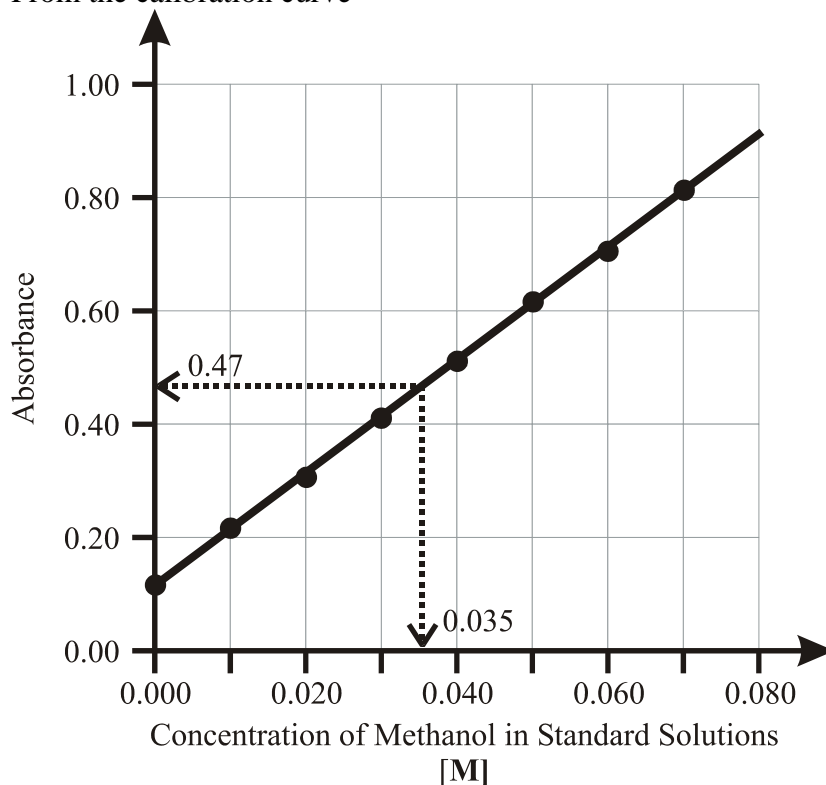
An absorbance of 0.47 corresponds to a methanol concentration of 0.035 M.
The solution used in the spectrophotometric analysis was a diluted solution that had a volume of 250.0 mL.
$n(CH_3OH) = 0.035 \times (250.0/1000) = 8.75 \times 10^{-2}$ mol.
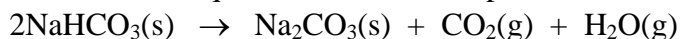This amount of methanol was in a solution that had an original volume of 20.0 mL
$c(CH_3OH, \text{ original}) = 8.75 \times 10^{-2} / (20.0/1000) = \textbf{0.44 M}$

Q8 **C** The main requirements for a primary standard are:
  a.   Has a known chemical formula
  b.   Does not deteriorate on storage or react with the atmosphere.
  c.   Can be readily obtained in a pure form.
  Cost of the reagent is the least important compared to these three requirements.

Q9 **D** The chemical equation for the decomposition of sodium hydrogen carbonate is
  $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$
  The mass loss will be due to the formation of CO_2 and H_2O.
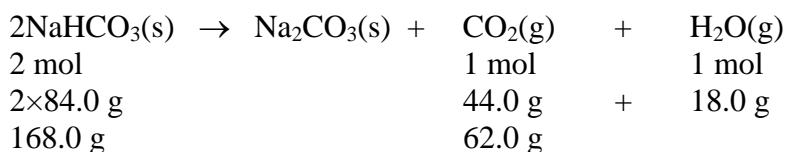 From the chemical equation 2 mol of sodium hydrogen carbonate will liberate
  1 mol of carbon dioxide and 1 mol of water
  $M(NaHCO_3) = 23.0 + 1.0 + 12.0 + 2 \times 16.0 = 84.0$ g mol^{-1}
  $M(CO_2) = 12.0 + 2 \times 16.0 = 44.0$ g mol^{-1}
  $M(H_2O) = 2 \times 1.0 + 16.0 = 18.0$ g mol^{-1}
  Consider the reaction

$2NaHCO_3(s)$	$\rightarrow$	$Na_2CO_3(s)$	+	$CO_2(g)$	+	$H_2O(g)$
2 mol				1 mol		1 mol
2×84.0 g				44.0 g	+	18.0 g
168.0 g				62.0 g		

  Therefore heating 168.0 g of $NaHCO_3$ will give a 62.0 g mass loss
  $m(NaHCO_3) = (\text{mass loss} / 62.0) \times 168.0 = (0.636 / 62.0) \times 168.0 = 1.723$ g
  $m(Na_2CO_3) = m(\text{sample}) - m(NaHCO_3) = 4.081 - 1.723 = 2.358$ g
  $\%(Na_2CO_3) = (2.358/4.081) \times (100/1) = \textbf{57.8 \%}$

Q10 C $n(AgNO_3) = c \times V = 0.100 \times (25.0/1000) = 2.50 \times 10^{-3}$ mol

$n(Ba(OH)_2) = c \times V = 0.0500 \times (20.0/1000) = 1.00 \times 10^{-3}$ mol

From the chemical equation;

$2AgNO_3(aq) + Ba(OH)_2(aq) \rightarrow Ag_2O(s) + Ba(NO_3)_2(aq) + H_2O(l)$

2 mol   1 mol   1 mol

The required mole ratio for the reaction is $n(AgNO_3) : n(Ba(OH)_2) = 2 : 1$

Since the actual $n(AgNO_3) : n(Ba(OH)_2) = 2.5 \times 10^{-3} : 1.00 \times 10^{-3}$

The $AgNO_3$ is in excess, therefore the limiting reagent is the $Ba(OH)_2$, so from the chemical equation

$n(Ag_2O) = n(Ba(OH)_2) = 1.00 \times 10^{-3}$ mol

$M(Ag_2O) = 2 \times 107.9 + 16.0 = 231.8$ g mol^{-1}

$m(Ag_2O) = n \times M = 1.00 \times 10^{-3} \times 231.8 = $ **0.232 g**

Q11 D Flame tests are qualitative analytical procedures, therefore cannot be used to determine the amount of substance present in a sample. Flame tests are also only suitable for certain metal elements. Only response D fulfils these criteria.

Q12 B To get a lower than expected result, the mass of precipitate must be less than that expected. Adding insufficient precipitating agent, usually added in excess of the required amount, would result in a lower mass of precipitate. Responses A, C & D would all result in higher masses of precipitate and as a result yield a higher than expected result.

SECTION B

Question 1 - [8 marks, 10 minutes]

a.   The following steps can be used to balance redox half-equations.
   1.   Identify reactants and products and balance all atoms other than H and O.
        4 S atoms on right hand side therefore need 2 $S_2O_3^{2-}$
        $2S_2O_3^{2-} \rightarrow S_4O_6^{2-}$
   2.   Balance oxygen atoms with water molecules.
        Balanced – no action required.
        $2S_2O_3^{2-} \rightarrow S_4O_6^{2-}$
   3.   Balance hydrogen atoms with H$^+$ ions.
        Balanced – no action required.
        $2S_2O_3^{2-} \rightarrow S_4O_6^{2-}$
   4.   Balance charge by adding electrons.
        Charge on left = -4   Charge on right -2; therefore needs 2 e$^-$
        $2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + $ **2e$^-$**
   5.   Add appropriate state symbols.
        $2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + $ 2e$^-$ [1 mark]

b.   The oxidation half-equation is: $2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + $ 2e$^-$
     The reduction half-equation is: $I_2(aq) + $ 2e$^-$ $\rightarrow 2I^-(aq)$
     Since both half-reactions involve a two electron process the overall chemical equation is the sum of the two half-equations.
     $2S_2O_3^{2-}(aq) + I_2 \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$ [1 mark]

c. $n(S_2O_3^{2-}) = c \times V = 0.0764 \times (17.81/1000) = $ **1.36×10^{-3} mol [1 mark]**

d.   From the chemical equation in b.
     $n(I_2) = \frac{1}{2} \times n(S_2O_3^{2-}) = \frac{1}{2} \times 1.36 \times 10^{-3} = $ **6.80×10^{-4} mol [1 mark]**

e.   Since: $I_2(aq) + $ 2e$^-$ $\rightarrow 2I^-(aq)$
     $n(I^-) = 2 \times n(I_2) = 2 \times 6.80 \times 10^{-4} = $ **1.36×10^{-3} mol [1 mark]**

f. $n(Cu^{2+}) = c \times V = 0.136 \times (10.00/1000) = $ **1.36×10^{-3} mol [1 mark]**

g. $n(Cu^{2+}) : n(I^-) = 1.36 \times 10^{-3} : 1.36 \times 10^{-3} =$ **1 : 1** **[1 mark]**

h.   The mole ratio determined in g. above is 1:1.

       The oxidation half-equation for the iodide ion is: $2I^-(aq) \rightarrow I_2(aq) + 2e^-$

       Therefore each iodide ion would effectively release one electron which will be accepted by the copper(II) ion. Therefore the copper(II) ion will be reduced to the copper(I) ion in the reaction.

       $\mathbf{Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)}$ **[1 mark]**

       Note: This copper(I) ion will then react with an iodide ion leading to the precipitation of copper(I) iodide, CuI.

Question 2 – [11 marks, 14 minutes]

a.   i.   A.   **Hollow Cathode Lamp [½ mark]**

                This lamp **emits light of a specific wavelength (energy) so that this corresponds to the energy required to excite electrons between two levels in the substance (element) being analysed. [1 mark]** Light will only be absorbed if its energy is equal to the energy difference between the two electron energy levels (absorption spectroscopy), otherwise it will pass through the substance unaltered. The amount of light absorbed will depend on the amount of substance present so that this method can be used as a quantitative tool.

     ii.   B.   **Burner [½ mark]**

                This **converts the sample into an atomic vapour** and places this vapour in the light path where the atoms of the element being analysed can absorb the energy from the light beam. **[1 mark]**

     iii.   C.   **The monochromator [½ mark]**

                This acts as a **light filter and selects the wavelength of the light** absorbed by the atoms from the sample that is to be analysed. **[1 mark]**

     iv.   D.   **Detector [½ mark]**

                This **measures the intensity of the light beam**. When atoms being analysed in the sample absorb light from the beam, the intensity of the beam decreases. This decrease is proportional to the concentration of the atoms in the sample. **[1 mark]**

b.   Correct plotting of data and labelling axes required to obtain full marks.
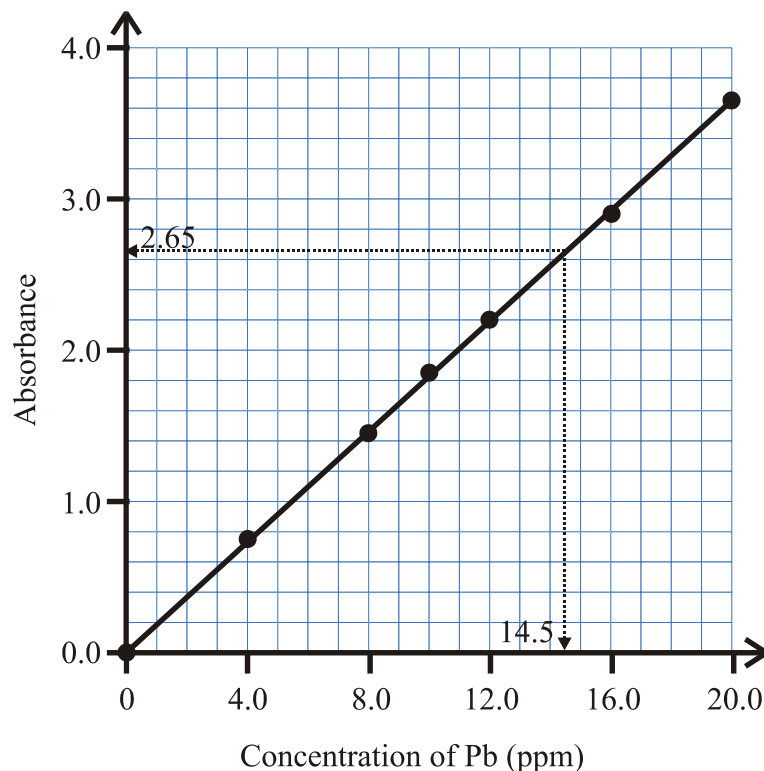
Concentration of Pb (ppm) **[2 marks]**

c. i. From the calibration curve an absorbance of 2.65 corresponds to a lead
concentration of **14.5 ppm. [1 mark]**

ii. 14.5 ppm = 14.5 g per 1000000 g of solution.
Since for the solution 1 mL = 1 g
$14.5 / 1000000 = 1.45 \times 10^{-5}$ g mL^{-1}
The sample was 100.0 mL
m(Pb in sample) = $1.45 \times 10^{-5} \times 100 = \mathbf{1.45 \times 10^{-3}}$ **g [1 mark]**

iii. m(sample) = 3.852 g
Pb content per g of sample = $1.45 \times 10^{-3} / 3.852 = 3.76 \times^{-4}$ g per g
Pb content (in ppm) = $3.76 \times 10^{-4} \times 1000000 = \mathbf{376}$ **ppm [1 mark]**

Question 3 - [5 marks, 6 minutes]
a. Using the retention times, since the two gas-liquid chromatogram were obtained under
the same conditions, the trihalomethane compounds that are present in the water sample
are **trichloromethane, CHCl$_3$ and dibromochloromethane, CHBr$_2$Cl. [1 mark]**
b. Since the gas-liquid chromatogram in *Diagram I* had equal molar amounts of the
compounds, comparison of the peak heights, while not as exact as the area under the
curve that needs to be measured for exact determination of amounts, in *Diagram II*
indicates that there is **more trichloromethane, CHCl$_3$, present than
dibromochloromethane, CHBr$_2$Cl. [1 mark]**
c. The two gas-liquid chromatograms are being compared and **the retention times are
being used to identify the compounds** present in the water sample. The **retention
time is determined by the absorption-desorption of the substance** as it passes
through a **length of column** containing the **stationary phas**e with the passage of the
mobile phase at a given **flow rate** and at a **specific temperature**. **Any changes** in
these conditions that the gas-liquid chromatogram was obtained under **could change
the retention times for the substances present**, therefore **not allowing the correct
identification of the compounds**. **[1 mark]**

d. The two conditions that can be readily changed are; **the carrier gas (mobile phase) flow rate [1 mark] and the temperature that the chromatograph is operating at [1 mark].**
The length of the column, type of material used as the stationary phase and the actual carrier gas being used can also be changed, but these usually are less easily achieved.

Question 4 - [4 marks, 5 minutes]
a. $M(BaSO_4) = 137.3 + 32.1 + 4\times16.0 = 233.4$ g mol^{-1} **[1 mark]**
$m(BaSO_4) = 25.777 - 23.219 = 2.486$ g
$n(BaSO_4) = m / M = 2.486 / 233.4 = \mathbf{1.065\times10^{-2}}$ **mol [1 mark]**
b. $n(SO_4^{-2}) = n(BaSO_4) = 1.065\times10^{-2}$ mol
$M(SO_4^{2-}) = 32.1 + 4\times16.0 = 96.1$ g mol^{-1}
$m(SO_4^{2-}) = n \times M = 1.065\times10^{-2} \times 96.1 = \mathbf{1.023}$ **g [1 mark]**
$\%(SO_4^{2-}) = (m(SO_4^{2-}) / m(sample)) \times (100/1)$
$\%(SO_4^{2-}) = (1.023 / 2.279) \times (100/1) = \mathbf{44.9\%}$ **[1 mark]**