STUDENT NAME: SOLUTIONS.

Year 11 VCE – CHEMISTRY
Unit 2: Written Examination – November 2011

Teachers' use only	
Section A (20)	
Section B (64)	
Total (84)	
Percentage (%)	

Tick your teacher's name	
Dr Fleming	
Miss Georganakis	
Mrs Webb	

QUESTION AND ANSWER BOOKLET

Reading Time: 15 minutes **Writing Time: 1 hour 30 minutes**

Section	*Number of questions*	*Total Marks*
A	**20**	**20**
B	**8**	**64**

Materials
Question and answer booklet of **15** pages.
Answer sheet for multiple-choice questions.
Data sheet.
You should have at least one HB pencil and an eraser.
An approved scientific calculator may be used and a ruler calibrated in millimetres.

The Task
Please ensure that you **write your name** and **tick your teacher's name** in the space provided on this booklet and in the space provided on the answer sheet for multiple-choice questions.
This paper consists of two sections, Section A and Section B.
Answer **all** questions from Section A. Section A is worth 20 marks.
Section A questions should be answered on the answer sheet provided for multiple-choice questions.
Answer **all** questions from Section B. Section B is worth 64 marks.
Section B questions should be answered in the spaces provided in this booklet.
There is a total of 84 marks available.
Working space is provided throughout this booklet.
All written responses should be in English.

At the end of the task
Place the answer sheet for multiple-choice questions inside the front cover of this booklet and hand both in.

SECTION A: MULTIPLE-CHOICE QUESTIONS (20 marks, 25 minutes)

This section contains 20 multiple choice questions.
For each question choose the response that is correct or that best answers the question.
Indicate your answer **on the answer sheet provided**.
Choose only **one** answer for each question.
A correct answer scores 1, an incorrect answer scores 0. Marks will **not** be deducted for incorrect answers.No marks will be given if more than one answer is completed for any question.

Question 1

Which one of the following contains the least number of molecules?

A. 1 g CH_4
B. 1 g C_2H_6
C. 1 g C_3H_8
D. 1 g C_4H_{10}

Question 2

The number of ions in 0.5 mol of sodium carbonate, Na_2CO_3 is closest to

A. 3.0×10^{23}
B. 4.5×10^{23}
C. 6.0×10^{23}
D. 9.0×10^{23}

Question 3

A sample of vinegar containing 0.200 mol of ethanoic acid, CH_3COOH, has a concentration of 0.250 mol L^{-1} of ethanoic acid. What is the volume of the solution?

A. 8.00 mL
B. 12.5 mL
C. 800 mL
D. 1.25 L

Question 4

If a sample of gas in a container of fixed volume is heated, which of the following will **not** occur?

A. The average speed of the molecules will increase.
B. The pressure exerted by the gas will increase.
C. The density of the gas will increase.
D. The average frequency of collisions with the walls will increase.

Question 5

The majority of nitrogen found in the biosphere is present as

A. N_2

B. NO_3^-

C. NH_3

D. NO_2

Question 6

The following ions could act as bases. Which one has the least tendency to accept protons?

A. NO_3^-

B. NH_3

C. SO_3^{2-}

D. CO_3^{2-}

Question 7

The sample of gas that would occupy the largest volume at SLC is

A. 1.0 g CH_4

B. 1.0 g O_2

C. 1.0 g CO_2

D. none of the above as all of the gases would occupy 24.5 L

Question 8

Which of the following would **not** be a source of carbon dioxide?

A. the burning of fossil fuels

B. fermentation of sugar to ethanol

C. the production of calcium oxide from calcium carbonate

D. photosynthesis

Question 9

Which of the following is a weak, diprotic acid?

A. HCOOH

B. H_2SO_4

C. $(COOH)_2$

D. C_2H_2

Question 10

A flask of mass 80.0 g is filled with CO_2 ($M_r = 44$). Its total mass is now 82.2 g. If the CO_2 is replaced with the same amount in moles of CO ($M_r = 28$) under the same conditions, what will the total mass of the flask be?

A. 80.14 g
B. 81.4 g
C. 82.2 g
D. cannot be determined

Question 11

The Contact process for the synthesis of sulphuric acid involves several stages. A key reaction is the conversion of sulphur dioxide to sulphur trioxide according to the equation:

$$2SO_2(g) + O_2 \rightarrow 2SO_3(g)$$

The maximum volume of sulphur trioxide, in litres, that can be prepared from 60 L of SO_2 and 60 L of O_2, **if all gases are measured at the same temperature and pressure and assuming the reaction goes to completion**, is

A. 30
B. 60
C. 90
D. 120

Question 12

A Brønsted-Lowry acid is defined as

A. an electron donor
B. an electron acceptor
C. a proton donor
D. a proton acceptor

Question 13

The pH of a solution of 0.1 M K_2HPO_4 (aq) was found to be 9.3. The best explanation of this is

A. The K^+ ions form KOH in solution.
B. K_2HPO_4 is a proton acceptor.
C. The HPO_4^{2-} ions are ampholytes which preferentially donate protons to water molecules.
D. The HPO_4^{2-} ions are ampholytes which preferentially accept protons from water molecules.

Question 14

Which substance can be dissolved in water to give a 0.1 M solution with a high pH and a high electrical conductivity?

A. HCl

B. NaCl

C. NH_3

D. NaOH

Question 15

The pH of solution **X** is 1 and that of **Y** is 2. Which statement is correct about the hydrogen ion concentration in the two solutions?

A. $[H^+]$ in **X** is half that of **Y**

B. $[H^+]$ in **X** is twice that of **Y**

C. $[H^+]$ in **X** is one tenth that of **Y**

D. $[H^+]$ in **X** is ten times that of **Y**

Question 16

A simple way of detecting ozone in polluted air is to bubble the air through a potassium iodide solution. In a redox reaction, ozone oxidises colourless iodide ions to yellow-brown iodine. The correct equation for this reaction is

A. $2O_3(g) + 2I^-(aq) \rightarrow I_2(aq) + 3O_2(g)$

B. $O_3(g) + 2I^-(aq) + 3H^+(aq) \rightarrow I_2(aq) + 3OH^-(aq)$

C. $O_3(g) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + H_2O(l) + O_2(g)$

D. $O_3(g) + 2I^-(aq) + H_2O(l) \rightarrow I_2(aq) + 3OH^-(aq)$

Question 17

Which of the following pairs of substances when mixed, should react?

A. $Sn^{2+}(aq)$ and $Fe^{2+}(aq)$

B. $Ni^{2+}(aq)$ and $Sn^{2+}(aq)$

C. $Zn^{2+}(aq)$ and Fe(s)

D. Ni(s) and $Sn^{2+}(aq)$

Question 18

In which of the following media would iron corrode at the greatest rate?

A. Distilled water

B. Tap water

C. Iced water

D. Carbonated tap water

The following information relates to Questions 19 and 20.

An experiment was conducted to determine the reactivity series for metals P, Q, R and S by examining any reactions which occur between the metals and solutions of the metal ions. Some of the results of the experiment were:

- Metal P reacts with metal ion S^{2+} but not with metal ion Q^{2+}
- Metal Q reacts with metal ion S^{2+} but not with metal ion R^{2+}

Question 19

Which of the following identifies the decreasing reactivity of these metals, starting with the most reactive metal?

A. Q, P, R, S

B. R, Q, P, S

C. S, Q, P, R

D. Q, R, S, P

Question 20

A galvanic cell is constructed using P^{2+}/P and R^{2+}/R half-cells.

Which of the following shows the expected reaction at the anode of this galvanic cell?

A. $R(s) \rightarrow R^{2+}(aq) + 2e^-$

B. $P(s) \rightarrow P^{2+}(aq) + 2e^-$

C. $R^{2+}(aq) + 2e^- \rightarrow R(s)$

D. $P^{2+}(aq) + 2e^- \rightarrow P(s)$

SECTION B: SHORT-ANSWER QUESTIONS (64 marks, 65 minutes)

This section contains 8 short-answer questions. Answer all questions in the spaces provided.
To obtain full marks for your responses you should:

- give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example $H_2(g)$; NaCl(s).

Question 1

a. Aqueous silver ions, Ag^+ ions, form a precipitate with aqueous XO_4^{3-}. Write a balanced equation for the reaction, including state symbols.

$3\,Ag^+(aq) + XO_4^{3-}(aq) \rightarrow Ag_3XO_{4(s)}$ balanced (1 mark) states (1 mark)

2 marks

b. When 41.2 mL of an aqueous solution of 0.2040 M Ag^+ is added to a solution containing an excess of XO_4^{3-} ions, 1.172 g of the precipitate is formed.

i. Calculate the amount (in moles) of Ag^+ ions used in the reaction.

$n(Ag^+) = c \times V$
$= 0.2040 \times 41.2 \times 10^{-3}$
$= 8.40 \times 10^{-3}$ mol (1 mark)

ii. Calculate the amount (in moles) of the precipitate formed.

$\frac{n(Ag_3XO_4)}{n(Ag^+)} = \frac{1}{3}$ (1 mark)

$n(Ag_3XO_4) = \frac{8.40 \times 10^{-3}}{3} = 2.80 \times 10^{-3}$ mol (1 mark)

iii. Calculate the molar mass of X. Show all working.

$n = \frac{m}{M}$, $2.80 \times 10^{-3} = \frac{m(Ag_3XO_4)}{M(Ag_3XO_4)}$

$M(Ag_3XO_4) = \frac{1.172}{2.80 \times 10^{-3}} = 418.6$ (1 mark)

$3 \times 107.9 + X + 4 \times 16.0 = 418.6$
$X = 30.9$ (1 mark)

1 + 2 + 2 = 5 marks

Total 7 marks

Question 2

A neutralisation reaction between barium hydroxide and sulphuric acid was performed.

a. Write a balanced chemical equation for the reaction between the barium hydroxide and sulphuric acid solutions.

(1 mark - correct reactant + products)

$Ba(OH)_{2(aq)} + H_2SO_{4(aq)} \longrightarrow BaSO_{4(s)} + 2H_2O_{(l)}$

(1 mark - correct balancing + states.)

2 marks

b. Calculate the mass of barium hydroxide powder needed to make 100.0 mL of 0.050 M solution.

$n(Ba(OH)_2) = c \times V = 0.050 \times 0.1000 = 5.0 \times 10^{-3}$ mol (1 mark)

$m(Ba(OH)_2) = n \times M = 5.0 \times 10^{-3} \times 171.3 = 0.86$ g (1 mark)

2 marks

c. Explain why barium hydroxide conducts electricity when dissolved in water.

Barium hydroxide solid consists of barium ions and hydroxide ions bonded together in a lattice. Dissolving in water breaks the bonds between the ions and allows them to move independently so that charge is carried in the solution.

1 mark

d. If 5.5 mL of a sulphuric acid solution was required to exactly neutralise a 20.0 mL aliquot of barium hydroxide, calculate the molarity of the sulphuric acid used in this experiment.

$n(Ba(OH)_2) = c \times V = 0.050 \times 0.0200 = 0.0010$ mol (1 mark)

$n(Ba(OH)_2) = n(H_2SO_4) = 0.0010$ mol (1 mark)

$c(H_2SO_4) = \frac{n}{V} = \frac{0.0010}{0.0055} = 0.18$ M (1 mark)

3 marks

e. State which pieces of laboratory equipment would be used to dispense the required volumes of barium hydroxide and sulphuric acid solutions.

$Ba(OH)_2 \rightarrow$ pipette (1 mark)

$H_2SO_4 \rightarrow$ burette (1 mark)

2 marks

Total 10 marks

Question 3

Ammonia gas has a high solubility in water of 75.1 L in 100 mL of water at 20 °C.

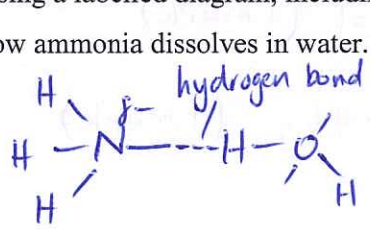
a. With the aid of a balanced chemical equation, explain why water containing dissolved ammonia would appear pink in the presence of phenolphthalein.

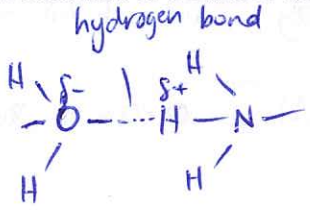
$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ (1 mark)

Ammonia reacting with water produces a basic solution which will change the colour of the indicator to pink. (1 mark)

2 marks

b. Using a labelled diagram, including the structural formulas of ammonia and water molecules, explain how ammonia dissolves in water.





(1 mark – correct drawing of molecules)

(1 mark – correct labelling of bonds)

Both ammonia and water are polar molecules. They form intermolecular (1 mark) hydrogen bonds, resulting in the high solubility of ammonia.

3 marks

c. The solubilities, in water, of two other gases are shown in the table below.

Gas	Solubility of gas (mL per 100 mL of water)		
	0 °C	20 °C	40 °C
oxygen	4.8	3.3	2.5
sulfur dioxide	7980	4250	2170

i. Describe an environmental problem caused by the high solubility of sulphur dioxide in water.

(1 mark) Sulfur dioxide gas in the atmosphere will dissolve in rainwater to produce sulfurous acid ($SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$). This will produce rain with lower pH than normal. This 'acid rain' can kill plants and ~~animals~~ lowers the (1 mark) pH of waterways which may cause destruction of the natural habitat.

ii. Some industries produce heated waste water. With reference to the information in the table of gas solubilities, explain the environmental problem caused by returning this heated water to natural waterways.

Heated water has a lower concentration of oxygen. (1 mark)
Lower oxygen concentration in waterways will impair functioning of aquatic life, possibly killing some species and disrupting the natural habitat. (1 mark)

2 + 2 marks

Total 9 marks

Question 4

Consider the reaction: $MnO_2(s) + 4HCl(aq) \rightarrow MnCl_2(aq) + Cl_2(g) + H_2O(l)$

a. If 0.320 mol of MnO_2 and 48.2 g of HCl are reacted, which reagent is in excess and by what mass?

$n(HCl) = \frac{48.2}{36.5} = 1.32$ mol (1 mark)

$\frac{n(HCl)}{n(MnO_2)} = \frac{4}{1}$ $\therefore n(HCl) = 4 \times n(MnO_2)$

$= 4 \times 0.320$ (1 mark)

$= 1.28$ mol.

HCl in excess by $1.32 - 1.28 = 0.04$ mol (1 mark)

$m(HCl) = n \times M = 0.04 \times 36.5 = 1.46$ g (1 mark)

4 marks

b. How many grams of Cl_2 will be produced?

$\frac{n(Cl_2)}{n(MnO_2)} = \frac{1}{1}$ (1 mark)

$n(Cl_2) = n \times M = 0.320 \times 71.0 = 22.7$ g (1 mark)

2 marks

Total = 6 marks

Question 5

For the **unbalanced** equation:

$$H_2S(aq) + Cr_2O_7^{2-}(aq) + H^+ \rightarrow Cr^{3+} + H_2O(l) + S(s)$$

answer the following questions.

a. Determine the oxidation number of the Cr atom in $Cr_2O_7^{2-}$

$(2 \times Cr) + (7 \times -2) = -2$, $2Cr = 12+$, $Cr = +6$ (1 mark)

1 mark

b. Identify the species that has been oxidised in the reaction. Explain your answer.

The S atoms have increased from an oxidation number of -2 to 0 (1 mark)

An increase in oxidation number is oxidation. H_2S has been oxidised. (1 mark)

2 marks

c. Write the oxidation half-equation (states not required).

$H_2S \rightarrow S + 2H^+ + 2\bar{e}$ (1 mark)

1 mark

d. Write the reduction half-equation (states not required).

$Cr_2O_7^{2-} + 14H^+ + 6\bar{e} \rightarrow 2Cr^{3+} + 7H_2O$ (1 mark)

1 mark

e. Use your half-equations to write a balanced overall reaction (states not required)

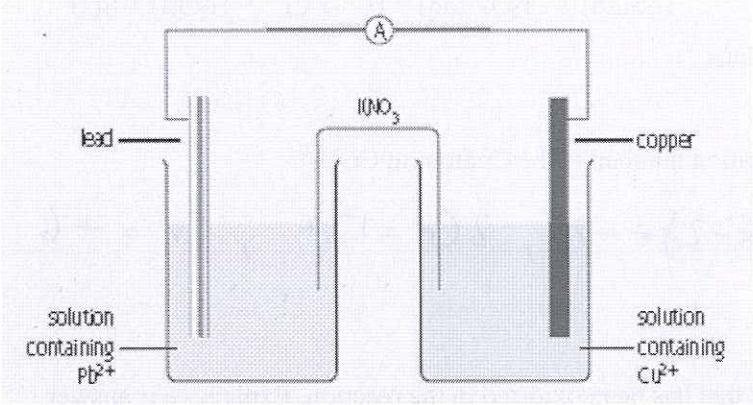
$3H_2S + Cr_2O_7^{2-} + 8H^+ \rightarrow 2Cr^{3+} + 7H_2O + 3S$ (1 mark)

1 mark

Total 6 marks

Question 6

A galvanic cell was made from copper and lead, as shown below.



a. Identify the reductant and oxidant that are reacting in this cell and write balanced half equations for their reactions. (1 mark)

Reductant is $Pb_{(s)}$, $Pb_{(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2\bar{e}$ (1 mark)

Oxidant is $Cu^{2+}_{(aq)}$, $Cu^{2+}_{(aq)} + 2\bar{e} \rightleftharpoons Cu_{(s)}$ (1 mark)
(1 mark)

4 marks

b. Write the balanced overall ionic equation for the cell reaction.

$Pb_{(s)} + Cu^{2+}_{(aq)} \rightarrow Cu_{(s)} + Pb^{2+}_{(aq)}$

1 mark

c. Explain, **in specific detail**, the movement of the cations and anions in the salt bridge.

Anions (NO_3^-) move toward solution containing Pb^{2+} to compensate for excess positive charge generated by oxidation of $Pb_{(s)}$. Cations (K^+) to solution containing Cu electrode to compensate for declining positive charge due to reduction of $Cu^{2+}_{(aq)}$.

2 marks

d. Explain why the salt used is KNO_3 and not K_2SO_4

The SO_4^{2-} anions would move to solution containing Pb^{2+} and these would form the insoluble $PbSO_4$ compound. NO_3^- anions do not react with Pb^{2+}.

1 mark

e. Which electrode would be the cathode?

Reduction occurs at the cathode ∴ $Cu_{(s)}$ electrode is cathode.

1 mark

Total 9 marks

Question 7

a. Dry ice is solid carbon dioxide. A 0.066 g sample of dry ice is placed in an evacuated 4.6 L vessel at 30 °C. Calculate the pressure, in kPa, inside the vessel after all the dry ice has been converted to CO_2 gas.

$n(CO_2) = \frac{0.066}{44.0} = 0.0015$ mol (1 mark)

$PV = nRT$, $P = \frac{nRT}{V}$

$= \frac{0.0015 \times 8.31 \times 303}{4.6}$ (1 mark)

$= 0.821$ kPa (1 mark)

3 marks

b. Ozone molecules in the stratosphere absorb much of the harmful radiation from the sun. Typically, the temperature and pressure of ozone in the stratosphere are 250 K and 1.0×10^{-3} atm. How many ozone molecules are present in 1.0 L of air under these conditions?

(1 mark) $P(O_3) = 1.0 \times 10^{-3} \times 101.3 = 0.101$ kPa

$PV = nRT$

$n = \frac{PV}{RT}$

$n(O_3) = \frac{0.101 \times 1.0}{8.31 \times 250}$ (1 mark)

$= 4.86 \times 10^{-5}$ mol (1 mark)

$N(O_3)$ molecules $= 4.86 \times 10^{-5} \times 6.02 \times 10^{23}$

$= 2.93 \times 10^{19}$ (1 mark)

4 marks

Total 7 marks

Question 8

Nitrogen gas composes 78% of air at sea level. Nitrogen is used by all living organisms and is an important raw material in the industrial production of chemicals.

a. Nitrogen gas must be 'fixed' before it can be used by living things.

i. Explain the meaning of 'fixed' in this context.

Atmospheric nitrogen is converted to a soluble nitrogen compound which can be used by plants.

(1 mark)

ii. Give an example of nitrogen being 'fixed' in a natural, non-biological process.

The high temperatures generated by lightning (or volcanoes) cause nitrogen to react with oxygen in the atmosphere to form nitrogen(II) oxide. (1 mark)

1+ 1 = 2 marks

b. An important industrial use of nitrogen is the manufacture of nitric acid (HNO_3). Initially, nitrogen and hydrogen gases are reacted to form ammonia gas which is then oxidised to produce the acid in a series of steps.

i. In ammonia production, air is used as the source of nitrogen gas in the reaction vessel rather than pure nitrogen gas. Suggest a reason for this.

Air is 78% nitrogen and costs nothing, whereas pure nitrogen would be expensive.

(1 mark)

ii. The final concentration of nitric acid from the process is 68 % (m/v). Calculate the pH of the acid at this concentration.

In 100mL there are 68 g of HNO_3.

$n(HNO_3) = \frac{m}{M} = \frac{68}{63}$ mol.

$c(HNO_3) = \frac{n}{V} = \frac{68}{63 \times 0.100} = 10.8$ M. (1 mark)

As HNO_3 is a strong monoprotic acid, $[H^+] = [HNO_3] = 10.8$ M (1 mark)

$pH = -\log[H^+] = -\log_{10} 10.8 = -1.0$. (1 mark)

1 + 3 = 4 marks

c. The principles of green chemistry are used extensively in the modern manufacture of nitric acid.

i. One of these principles is to maximise atom economy. Calculate the percentage atom economy for the modern method which uses the chemical reaction shown below.

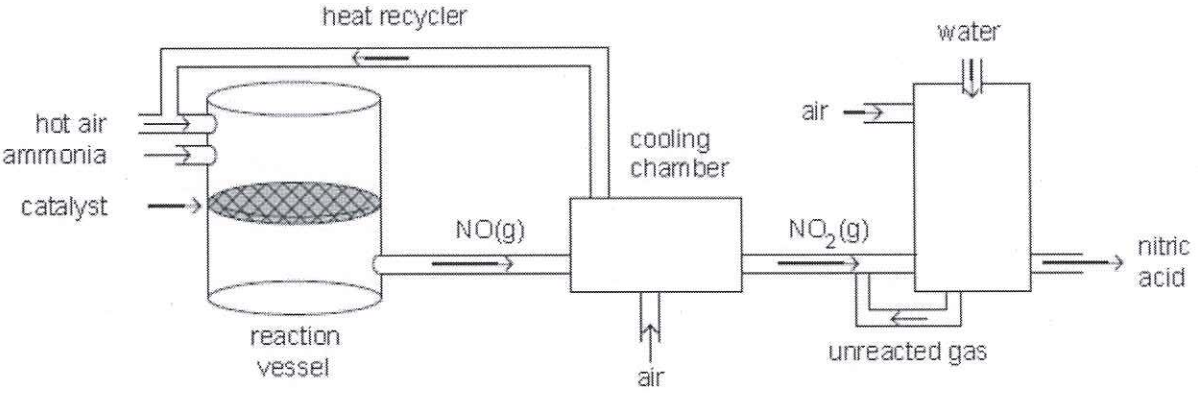
$$NH_3(g) + 2O_2(g) \rightarrow HNO_3(aq) + H_2O(l)$$

Reactants : $M(NH_3) + M(2O_2) = 17 + 64 = 81$ } (1 mark)

Product : $M(HNO_3) = 63$.

% atom economy $= \frac{63}{81} \times \frac{100}{1} = 78\%$ (1 mark)

ii. This simplified diagram shows the important steps in the modern manufacture of nitric acid.



Identify **two** applications of green chemistry used in the manufacturing process shown in the diagram.

Possibles include : (1) use of a catalyst
(2) minimising energy losses by recycling waste heat.
(3) recycling unreacted gases.

2 + 2 = 4 marks

Total = 10 marks

END OF QUESTION AND ANSWER BOOKLET