Trial Examination 2006

VCE Chemistry Unit 3

Written Examination

Question and Answer Booklet

Reading time: 15 minutes
Writing time: 1 hour 30 minutes

Student's Name: _____

Teacher's Name: _____

Structure of Booklet

Section	Number of questions	Number of questions to be answered	Marks	Suggested time (minutes)
A Multiple-choice	20	20	20	30
B Short-answer	6	6	45	60
			Total 65	Total 90

Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, one scientific calculator.
Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied

Question and answer booklet of 13 pages with a detachable data sheet in the centrefold.
Answer sheet for multiple-choice questions.

Instructions

Detach the data sheet from the centre of this booklet during reading time.
Please ensure that you write **your name** and your **teacher's name** in the space provided on this booklet and in the space provided on the answer sheet for multiple-choice questions.
All written responses must be in English.

At the end of the examination

Place the answer sheet for multiple-choice questions inside the front cover of this booklet and hand them in.

Students are NOT permitted to bring mobile phones and/or any other electronic communication devices into the examination room.

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2006 VCE Chemistry Unit 3 Written Examination.

SECTION A: MULTIPLE-CHOICE QUESTIONS

Instructions for Section A

Answer all questions in pencil on the answer sheet provided for multiple-choice questions. Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1, an incorrect answer scores 0. Marks will **not** be deducted for incorrect answers. No mark will be given if more than one answer is completed for any question.

Question 1

The retention time of a substance measured using HPLC analysis is **least** likely to be affected by a change in the

A. type of solvent used.
B. concentration of the substance.
C. temperature at which the chromatogram is produced.
D. rate of flow of the solvent.

Question 2

During the production of sulfuric acid by the Contact process, the three reactions represented by the equations below occur.

I $S_{(l)} + O_{2(g)} \rightarrow SO_{2(g)}$

II $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

III $SO_{3(g)} + H_2SO_{4(l)} \rightarrow H_2S_2O_{7(l)}$

Which of the following statements is true for all three of the reactions represented above?

A. All are exothermic.
B. All involve the oxidation of sulfur.
C. All rely on high temperatures to increase the reaction rate.
D. All occur at elevated pressures to ensure maximum yield.

Question 3

Oysters are a delicacy in many restaurants. Occasionally oysters are found to contain levels of mercury unsafe for human consumption. For this reason, oyster farms regularly test their product to determine levels of mercury in concentrations of μg/g or below. The most appropriate technique for this determination of mercury in oysters is

A. qualitative analysis using a gravimetric procedure.
B. qualitative analysis using atomic absorption spectrometry.
C. quantitative analysis using a gravimetric procedure.
D. quantitative analysis using atomic absorption spectrometry.

Question 4

The pH of a solution formed when 20.00 mL of 0.00100 M HCl is mixed with 20.00 mL of 0.00100 M $Ba(OH)_2$ will be

A. 3.30
B. 7.00
C. 10.3
D. 10.7

Question 5

In which of the following reactions would the position of equilibrium be unaffected by a change in the pressure of the equilibrium mixture as a result of a change in the volume of the reaction vessel?

A. $H_{2(g)} + CO_{2(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$ $\Delta H = +42$ kJ mol^{-1}

B. $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$ $\Delta H = -92$ kJ mol^{-1}

C. $C_2H_{6(g)} \rightleftharpoons C_2H_{4(g)} + H_{2(g)}$ $\Delta H = +138$ kJ mol^{-1}

D. $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$ $\Delta H = -58.2$ kJ mol^{-1}

Question 6

Phosphorus pentachloride decomposes according to the following equation:

$$PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)} \quad \Delta H > 0, \quad K = 1.70 \text{ M at } 250°C$$

If 1.0 mol of the reactant and 1.0 mol of each product were introduced and allowed to mix in a thermally insulated vessel, the temperature of the reaction mixture would

A. increase, and the mass of PCl_5 would increase.

B. increase, and the mass of PCl_5 would decrease.

C. decrease, and the mass of PCl_5 would increase.

D. decrease, and the mass of PCl_5 would decrease.

Question 7

Sulfur trioxide reacts with water according to the equation:

$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$$

During the production of sulfuric acid by the Contact process, this reaction is not used because

A. the rate of reaction is too slow.

B. the reaction is highly exothermic.

C. a catalyst is needed for the reaction to occur at normal operating temperatures.

D. the equilibrium constant for the reaction is very small.

Question 8

0.16 g of limestone (impure $CaCO_3$) reacts completely with 100.0 mL of 0.020 M HCl.
The percentage by mass of $CaCO_3$ in the limestone is

A. 6.0

B. 31

C. 63

D. 99

Question 9

Chromium metal may be extracted from the mineral chromite, $Fe(CrO_2)_2$. The oxidation state of chromium in chromite is

A. +1

B. +2

C. +3

D. +4

Question 10

During the analysis of a hydrocarbon, an 8.75 g sample undergoes complete combustion with oxygen to produce 14.6 L of carbon dioxide at SLC. The molecular formula of the hydrocarbon could be

A. CH_4
B. C_2H_6
C. C_3H_6
D. C_3H_8

Question 11

A 0.01 M solution of a weak, monobasic base is titrated with a 0.01 M solution of a strong, monoprotic acid. At the equivalence point of this titration, the pH of the reaction mixture will be

A. less than 7.
B. 7 exactly.
C. greater than 7.
D. less than or greater than 7 depending on the particular strong acid and weak base used.

Question 12

When forensically testing a material, the sample should ideally be preserved so that tests can be repeated if required. Many analytical techniques are destructive; that is, the sample is destroyed during the analysis. Which of the following analytical techniques would preserve the sample being tested?

A. atomic absorption spectrometry
B. gravimetric analysis
C. UV-visible spectrometry
D. acid-base volumetric analysis

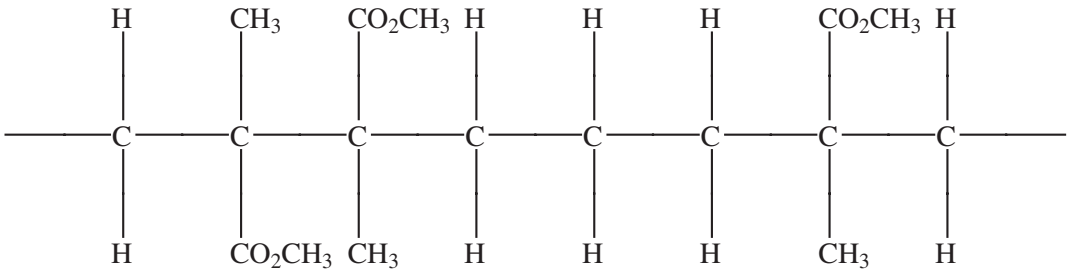
Question 13

Which product has the greatest concentration in the resultant mixture when 3.0 mol of chlorine gas reacts with 1.0 mol of methane in the presence of sunlight?

A. CH_3Cl
B. CH_2Cl_2
C. $CHCl_3$
D. HCl

Question 14

The diagram below shows a segment of a polymer chain.



This segment could have been produced using

A. $CH_2C(CH_3)CO_2CH_3$ and CH_2CH_2.
B. $CH_3CO_2C(CH_3)CH_2$ only.
C. $CH_3CHCHCO_2CH_3$ and CH_2CH_2.
D. $CH_3CO_2C(CH_3)C(CH_3)CO_2CH_3$ and CH_2CH_2.

Question 15

Lead(II) nitrate and aluminium chloride solutions when mixed together produce a precipitate of lead(II) chloride according to the equation:

$$3Pb(NO_3)_{2(aq)} + 2AlCl_{3(aq)} \rightarrow 3PbCl_{2(s)} + 2Al(NO_3)_{3(aq)}$$

When 20.00 mL of a 0.10 M solution of aluminium chloride was added to an excess of lead(II) nitrate solution, 0.56 g of lead(II) chloride (M = 278.2 g mol^{-1}) was recovered.

The percentage yield for this experiment was

A. 24%

B. 37%

C. 67%

D. 100%

Question 16

Sulfuric acid reacts with iron(III) oxide according to the equation:

$$3H_2SO_{4(aq)} + Fe_2O_{3(s)} \rightarrow Fe_2(SO_4)_{3(aq)} + 3H_2O_{(l)}$$

In this reaction, sulfuric acid acts as

A. a dehydrating agent and an oxidant.

B. an oxidant only.

C. an acid only.

D. both an oxidant and an acid.

Question 17

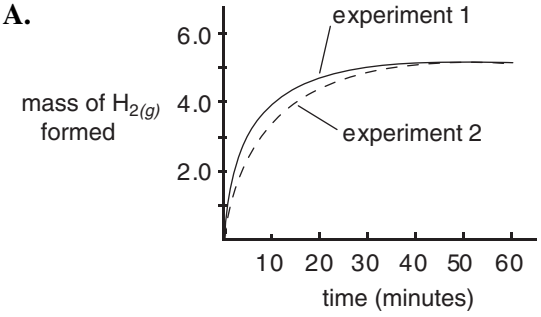
Hydrogen may be prepared industrially by reacting methane with steam according to the equation:

$$CH_{4(g)} + H_2O_{(g)} \rightleftharpoons 3H_{2(g)} + CO_{(g)} \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

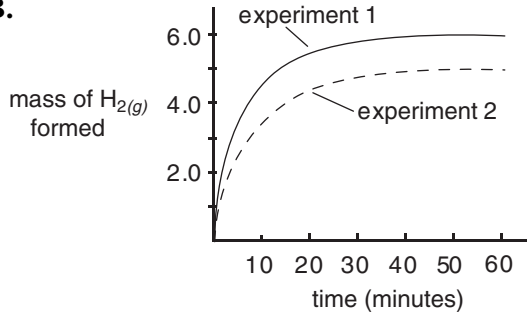
In an experiment (experiment 1), 25.0 g of methane reacted with excess steam at 700°C. The mass of hydrogen formed was recorded at intervals. In a second experiment (experiment 2), 25.0 g of methane was reacted with excess steam at 400°C, and again the hydrogen formed was recorded.

Which of the graphs below shows the expected results for experiments 1 and 2?

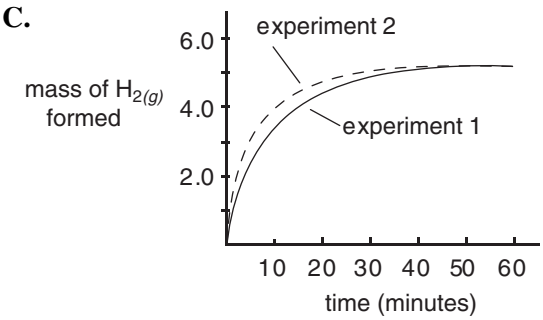
A.



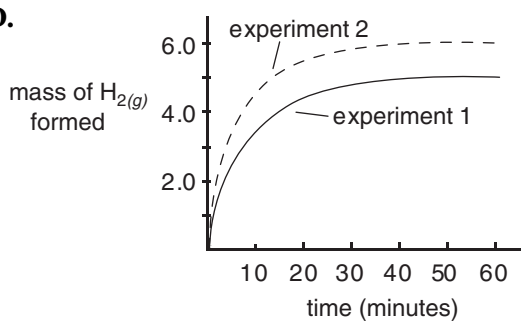
B.



C.

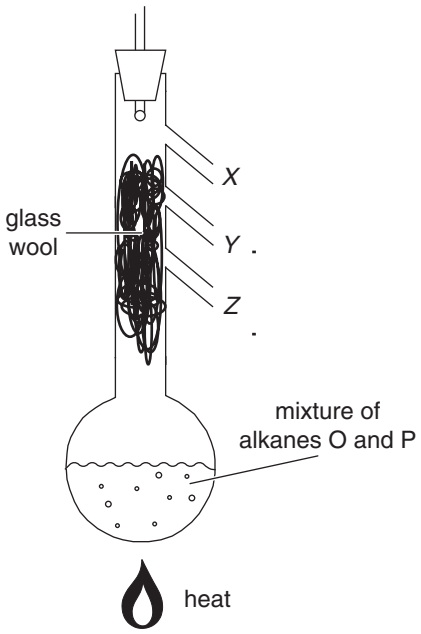


D.



Use the following information to answer Questions 18 and 19.

A mixture of two hydrocarbons, alkane O (boiling point 36°C) and alkane P (boiling point 98°C), is heated in a fractional distillation flask as shown below. Fractions may be removed at points *X*, *Y*, and *Z*.



Question 18

The fraction removed at *Z* is likely to have the

A. highest boiling point and contain a high proportion of alkane O.

B. highest boiling point and contain a high proportion of alkane P.

C. lowest boiling point and contain a high proportion of alkane O.

D. lowest boiling point and contain a high proportion of alkane P.

Question 19

If the pressure within the apparatus was significantly reduced, the fraction collected at *Y* is likely to contain a high proportion of

A. alkane O because the boiling temperatures of the alkanes have been decreased.

B. alkane P because the boiling temperatures of the alkanes have been decreased.

C. alkane O because the boiling temperatures of the alkanes have been increased.

D. alkane P because the boiling temperatures of the alkanes have been increased.

Question 20

Swimming pools may be chlorinated by dissolving gaseous chlorine in the water, where the following reaction occurs.

$$Cl_{2(g)} + 3H_2O_{(l)} \rightleftharpoons Cl^-_{(aq)} + ClO^-_{(aq)} + 2H_3O^+_{(aq)}$$

A saltwater pool may be chlorinated in the same way. For a given amount of chlorine, added to a given volume of water, the pH of the water in the saltwater pool would be

A. greater than that of the freshwater pool.

B. less than that of the freshwater pool.

C. the same as that of the freshwater pool.

D. greater than 7 because the sodium ions in salt react with water to produce hydroxide ions.

SECTION B: SHORT-ANSWER QUESTIONS

Instructions for Section B

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

The reaction occurring in the Haber process for the synthesis of ammonia is described by the equation:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \quad K = 0.00659 \text{ at } 450°C$$

a. Write the expression for the equilibrium constant for this reaction.

1 mark

b. 0.020 mol of nitrogen gas was introduced into a 0.50 L vessel containing hydrogen gas at 450°C. When equilibrium was established there was 0.0050 mol of ammonia in the vessel. Calculate the concentration of hydrogen gas present in the vessel at equilibrium.

4 marks

c. Calculate the value of the equilibrium constant, K, at 450°C for the reaction shown by the equation:

$$4NH_{3(g)} \rightleftharpoons 2N_{2(g)} + 6H_{2(g)}$$

1 mark

Total 6 marks

Question 2

Pure iron dissolves in dilute sulfuric acid according to the ionic equation:

$$Fe_{(s)} + 2H^+_{(aq)} \rightarrow Fe^{2+}_{(aq)} + H_{2(g)}$$

The Fe^{2+} ions formed can be oxidised to Fe^{3+} ions by reaction with an acidified, aqueous solution of potassium permanganate.

$$5Fe^{2+}_{(aq)} + MnO_4^-{}_{(aq)} + 8H^+_{(aq)} \rightarrow 5Fe^{3+}_{(aq)} + Mn^{2+}_{(aq)} + 4H_2O_{(l)}$$

In order to determine the percentage iron present in steel wool, a 0.440 g sample was dissolved in excess sulfuric acid. This was then transferred to a volumetric flask and made up to a volume of 100.0 mL. A 25.00 mL aliquot was then titrated with an acidified 0.0198 M potassium permanganate solution. A titre of 19.71 mL was recorded.

a. Determine the amount (in mol) of MnO_4^- present in the titre.

_____

_____

1 mark

b. Determine the amount (in mol) of Fe^{2+} present in the 100.0 mL volumetric flask.

_____

_____

_____

2 marks

c. Determine the percentage by mass of iron in the steel wool.

_____

_____

_____

2 marks

d. Name another simple laboratory technique that could be used to determine the iron content of the steel wool.

_____

1 mark

e. Name an instrumental technique that could be used to determine the iron content of the steel wool.

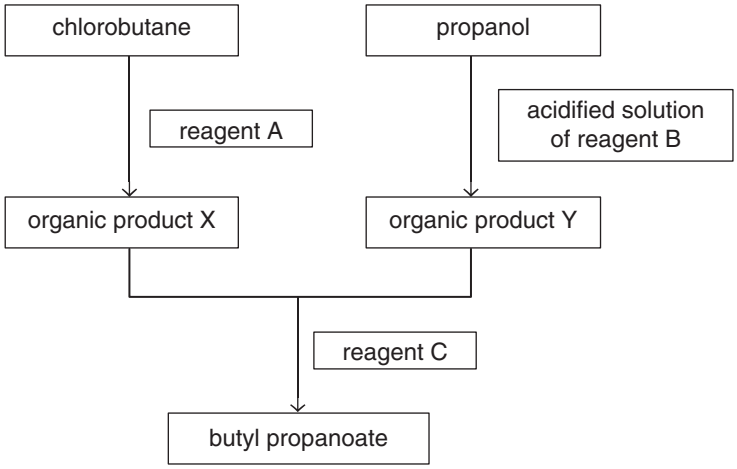
_____

1 mark

Total 7 marks

Question 3

Consider the following scheme which shows the reactions of some organic compounds, starting with chlorobutane and propanol.



a. Write the semi-structural formulas for

i. organic product X

_____

ii. organic product Y

_____

iii. butyl propanoate

_____

1 + 1 + 1 = 3 marks

b. Write the chemical formula for a suitable substance to use as

i. reagent A

_____

ii. reagent B

_____

0.5 + 0.5 = 1 mark

c. Write the chemical formula for an inorganic product formed at the same time as

i. organic product X

_____

ii. butyl propanoate

_____

0.5 + 0.5 = 1 mark

d. If the starting material had been butene instead of chlorobutane, write an equation to show one additional step that would be needed in order to complete the synthesis of butyl propanoate.

_____

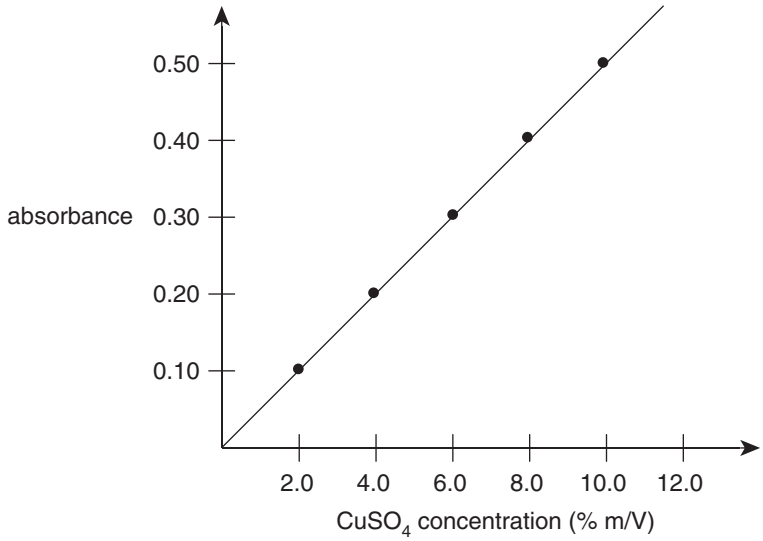
1 mark

Total 6 marks

Question 4

Copper(II) sulfate solutions, when treated with dilute ammonia solution, form a deep blue colour due to the formation of a tetrammine copper(II) complex. An impure, approximately 5 M copper(II) sulfate solution was to be analysed using a UV-visible spectrophotometer.

A series of copper(II) sulfate standards was treated with ammonia solution. Using a spectrophotometer set at a wavelength of 610 nm, the standard curve, shown below, was prepared.



a. If the approximately 5 M copper(II) sulfate solution was to be analysed using this spectrophotometer and the standard curve shown, by what factor must the solution be diluted with water prior to taking an absorbance reading? Show the working used to obtain your answer.

_____

_____

_____

_____

_____

3 marks

b. State any assumptions made about the impurities in the copper(II) sulfate solution when completing this analysis.

_____

_____

1 mark

c. Based on the experiment described, what colour is light of wavelength 610 nm likely to be? Explain your choice.

_____

_____

_____

2 marks

Total 6 marks

Question 5

Ethene reacts with water in the presence of a phosphoric acid catalyst to produce ethanol.

$$C_2H_{4(g)} + H_2O_{(l)} \rightleftharpoons C_2H_5OH_{(aq)}$$

a. Which of the following terms could be used to describe the type of reaction occurring between water and ethene? Indicate your answer by placing a tick in one or more appropriate boxes.

hydrolysis	☐	**acid-base**	☐
substitution	☐	**redox**	☐
addition	☐	**condensation**	☐

1 mark

b. How does the presence of the phosphoric acid catalyst alter each of the following characteristics of the reaction? Indicate your answer by placing ticks in the appropriate columns.

Characteristic	Increased by the catalyst	Decreased by the catalyst	Unchanged by the catalyst
ΔH value			
Equilibrium yield of ethanol			
Rate of reverse reaction $C_2H_5OH_{(aq)} \rightleftharpoons C_2H_{4(g)} + H_2O_{(l)}$			

3 marks

c. Given that the density of ethanol is 0.785 g mL^{-1}, calculate the mass of ethene required to produce 5.00×10^3 mL of ethanol.

_____

_____

_____

_____

_____

3 marks

d. **i.** 2-pentene undergoes a similar reaction to ethene with water. Draw a full structural formula for one organic product which could result from the reaction of 2-pentene with water.

ii. Name the organic compound drawn in part **d. i.**

_____

1 + 1 = 2 marks
Total 9 marks

Question 6

Hydrogen peroxide (H_2O_2) is a chemical with a wide range of applications which include uses such as: antiseptic, bleaching agent, rocket fuel, the foaming of rubber and plastics, as well as sewage treatment.

a. Some uses of H_2O_2 are due to its strong oxidant properties. H_2O_2 is also a reductant, and can undergo self-oxidation and reduction to form oxygen gas and water.

$$2H_2O_{2(l)} \rightleftharpoons 2H_2O_{(l)} + O_{2(g)}$$

i. Write a balanced half-equation for the oxidation of H_2O_2 to form oxygen gas.

_____

ii. Write a balanced half-equation for the reduction of H_2O_2 to form water.

_____

iii. While H_2O_2 does undergo this self-redox reaction, solutions of H_2O_2 can be stored in a dark bottle on the bathroom shelf for an extended time. Suggest why this storage in a dark bottle is possible.

_____

_____

1 + 1 + 2 = 4 marks

b. H_2O_2 is also a weak acid, ionising according to the equation:

$$H_2O_{2(l)} + H_2O_{(l)} \rightleftharpoons HO_2^-{}_{(aq)} + H_3O^+{}_{(aq)}$$

The ionisation constant, K_a, for hydrogen peroxide is 2.27×10^{-12}.

i. Write an expression for K_a for H_2O_2.

ii. Calculate the concentration of a hydrogen peroxide solution in which the pH is 6.0.

1 + 2 = 3 marks

c. Like hydrogen peroxide, water is a weak acid, an oxidant and a reductant, and can undergo a reaction with itself according to the equation:

$$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + H_3O^+_{(aq)} \quad K = 1.0 \times 10^{-13} \text{ at } 60°C.$$

i. Is water acting as an acid, an oxidant or both in this reaction?

_____

ii. Calculate the pH of pure water at 60°C.

_____

_____

iii. Indicate the acidity or basicity of pure water at 60°C by placing a tick in the appropriate box below.

acidic ☐

basic ☐

neutral ☐

0.5 + 1 + 0.5 = 2 marks

d. Commercially-available solutions of hydrogen peroxide are labelled using a concentration scale where a '1 volume' solution is equivalent to the volume of oxygen gas evolved by 1.0 L of solution at STP. Thus 1.0 L of a '10 volume' solution of hydrogen peroxide would evolve 10 L of oxygen at STP.

Find the 'volume' concentration of a hydrogen peroxide solution which has a concentration of 60 g L^{-1}.

_____

_____

_____

_____

_____

_____

2 marks

Total 11 marks

END OF QUESTION AND ANSWER BOOKLET