



VCE CHEMISTRY 2012

YEAR 11 TRIAL EXAM UNIT 2

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Time allowed: 90 Minutes

Total marks: 72

Section A

Contains 24 Multiple Choice Questions
24 marks, 30 minutes

Section B

Contains 6 Short Answer Questions
48 marks, 60 minutes

To download the Chemistry Data Book please visit the VCAA website:

http://www.vcaa.vic.edu.au/vcaa/vce/studies/chemistry/publications/chemdata_2012-w.pdf

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Student Name.....

VCE Chemistry 2012 Year 11 Trial Exam Unit 2

Student Answer Sheet

There are 24 Multiple Choice questions to be answered by circling the correct letter in the table below. Use only a 2B pencil. If you make a mistake, erase and enter the correct answer. Marks will not be deducted for incorrect answers

<i>Question 1</i>	A	B	C	D	<i>Question 2</i>	A	B	C	D
<i>Question 3</i>	A	B	C	D	<i>Question 4</i>	A	B	C	D
<i>Question 5</i>	A	B	C	D	<i>Question 6</i>	A	B	C	D
<i>Question 7</i>	A	B	C	D	<i>Question 8</i>	A	B	C	D
<i>Question 9</i>	A	B	C	D	<i>Question 10</i>	A	B	C	D
<i>Question 11</i>	A	B	C	D	<i>Question 12</i>	A	B	C	D
<i>Question 13</i>	A	B	C	D	<i>Question 14</i>	A	B	C	D
<i>Question 15</i>	A	B	C	D	<i>Question 16</i>	A	B	C	D
<i>Question 17</i>	A	B	C	D	<i>Question 18</i>	A	B	C	D
<i>Question 19</i>	A	B	C	D	<i>Question 20</i>	A	B	C	D
<i>Question 21</i>	A	B	C	D	<i>Question 22</i>	A	B	C	D
<i>Question 23</i>	A	B	C	D	<i>Question 24</i>	A	B	C	D

VCE Chemistry 2012 Year 11 Trial Exam Unit 2

SECTION A – Multiple Choice Questions

(24 marks, 30 minutes)

*This section contains 24 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.)*

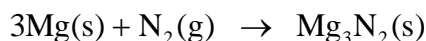
Question 1

Butanoic acid, C_3H_7COOH , is a weak acid. In a 0.050 M aqueous solution of butanoic acid, the concentration of the butanoate ion, $C_3H_7COO^-(aq)$, would be closest to

- A. 5.0×10^{-2} M
- B. 8.7×10^{-4} M
- C. 2.5×10^{-2} M
- D. 8.7×10^{-9} M

Question 2

The reaction between magnesium metal and nitrogen gas can be represented by the chemical equation



The mass of magnesium that would have reacted with excess nitrogen to form 2.610 g of the product would be

- A. 2.190 g.
- B. 0.629 g.
- C. 1.656 g.
- D. 1.886 g.

Question 3

Some companies have replaced polystyrene packaging foam pellets with ones that are made from cornstarch. The main green chemistry principle that this is an example of is

- A. the use of renewable raw materials to produce a product.
- B. reducing the production of waste materials during production.
- C. the use of catalysts to reduce the energy required to produce the product.
- D. avoiding the use of toxic chemicals to produce a product.

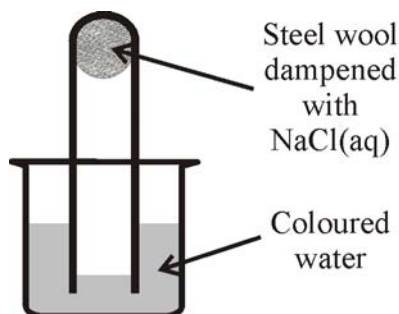
Question 4

200.0 mL of an aqueous solution with a cerium(IV) ion concentration of 0.0100 M was required to be prepared by dissolving solid hydrated cerium(IV) sulfate, $Ce(SO_4)_2 \cdot 4H_2O$, in deionised water. The mass of the solid required would be

- A. 0.665 g.
- B. 8.086 g.
- C. 0.809 g.
- D. 4.043 g.

Question 5

During an experimental investigation into the reactions involved in the wet corrosion of iron, the apparatus shown in the diagram was set up. After a few days



- A. no rust would be observed on the surface of the steel wool.
- B. the level of water in the tube containing the steel wool would have risen.
- C. a blue coloured deposit would be observed on the surface of the steel wool.
- D. the level of water in the tube containing the steel wool would have fallen.

Question 6

An aqueous solution contains carbonic acid, $\text{H}_2\text{CO}_3(\text{aq})$, ammonium, $\text{NH}_4^+(\text{aq})$, hydrogen carbonate, $\text{HCO}_3^-(\text{aq})$, and carbonate, $\text{CO}_3^{2-}(\text{aq})$ ions. The amphoteric substance present in this solution is the

- A. carbonate ion.
- B. ammonium ion.
- C. hydrogen carbonate ion.
- D. carbonic acid.

Question 7

Sodium ethoxide, $\text{Na}(\text{C}_2\text{H}_5\text{O})$, is classed as a superbases, because when it is dissolved in water, the ethoxide ion will completely react with and deprotonate water. Which one of the following species would have the lowest concentration when 0.1 mole of sodium ethoxide is dissolved in 1.0 L of deionised water?

- A. Hydrogen ion, $\text{H}^+(\text{aq})$.
- B. Ethanol, $\text{C}_2\text{H}_5\text{OH}(\text{aq})$.
- C. Sodium ion, $\text{Na}^+(\text{aq})$.
- D. Hydroxide ion, $\text{OH}^-(\text{aq})$.

Question 8

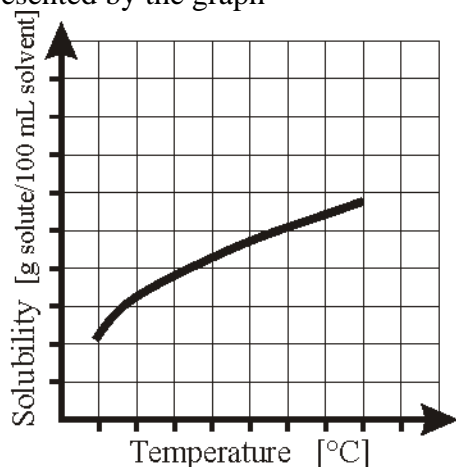
When a piece of copper wire is placed in an aqueous solution of silver nitrate, silver is deposited on the surface of the wire. In this reaction

- A. the silver ions are gaining electrons and the copper is acting as the oxidant.
- B. the copper is gaining electrons and the silver ions are acting as the oxidant.
- C. the silver ions are gaining electrons and the copper is acting as the reductant.
- D. the copper is gaining electrons and acting as the reductant.

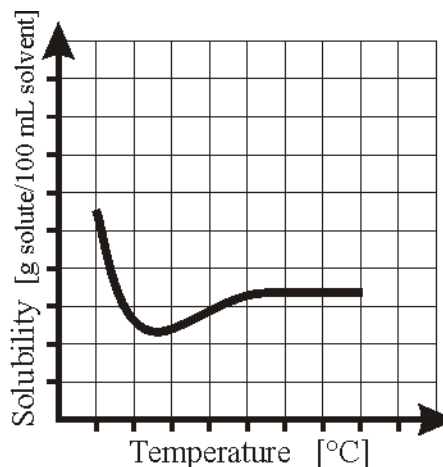
Question 9

The solubility curve for a gas, such as oxygen, between 10 °C and 80 °C would most probably be represented by the graph

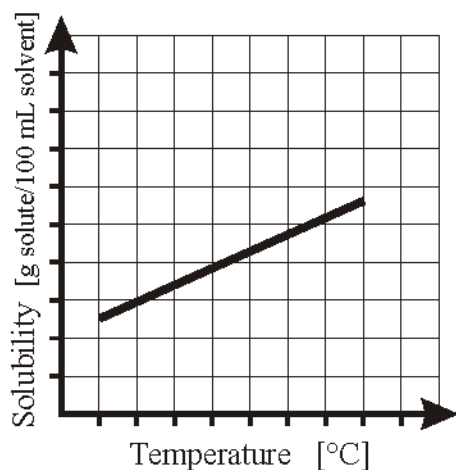
A.



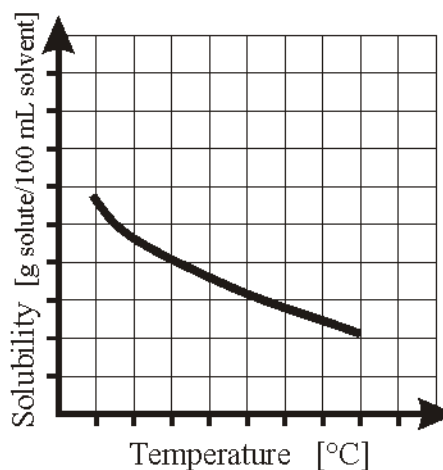
B.



C.



D.



Question 10

The latent heat of vaporisation is the amount of energy required to change a liquid into a gas at its boiling temperature. The latent heat of vaporisation for water is significantly higher than that for methane. The main contribution to this observation is

- A. the stronger covalent bonding present within the water molecules.
- B. the stronger dispersion forces present between the water molecules.
- C. the hydrogen bonding present between the water molecules.
- D. the covalent bonding between the water molecules.

Question 11

Dilute aqueous hydrochloric acid is slowly added, with mixing, to a tank containing an aqueous solution of sodium hydroxide. As the acid is added, the pH of the mixture will

- A. increase because the concentration of the hydrogen ion, $H^+(aq)$, is decreasing.
- B. decrease because the concentration of the hydrogen ion, $H^+(aq)$, is decreasing.
- C. increase because the concentration of the hydroxide ion, $OH^-(aq)$, is decreasing.
- D. decrease because the concentration of the hydrogen ion, $H^+(aq)$, is increasing.

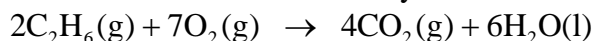
Question 12

From the listed molecular compounds, the one that is **least** likely to be soluble in water would be

- A. hexane, C₆H₁₄.
- B. ethanol, C₂H₆O.
- C. hydrogen chloride, HCl.
- D. glucose, C₆H₁₂O₆.

Question 13

The complete combustion of ethane can be described by the chemical equation



A mixture containing 280.0 mL of oxygen and 60.0 mL of ethane, both measured at SLC, was placed in a reactor and ignited with a spark. The volume of carbon dioxide produced at SLC would be

- A. 160.0 mL
- B. 120.0 mL
- C. 30.0 mL
- D. 80.0 mL

Question 14

The level of methane in the atmosphere has increased from about 1600 parts per billion (ppb) to about 1800 ppb over the past thirty years. Most of this increase in methane can be associated with

- A. burning fossil fuels.
- B. aircraft operations.
- C. volcanic activity.
- D. agricultural production.

Question 15

A 5000 L tank contained 350 kg of gaseous sulfur dioxide, SO₂(g), at 21 °C. The pressure exerted by this gas would be

- A. 1.9×10^2 kPa.
- B. 2.7×10^3 kPa.
- C. 19 kPa.
- D. 2.7 kPa.

Question 16

Ultraviolet radiation from the Sun striking the stratosphere

- A. will only cause the decomposition of ozone.
- B. will only result in the formation of ozone.
- C. will be reflected back into space by the ozone present.
- D. will result in both the formation and decomposition of ozone.

Question 17

A gas syringe contains a given amount of helium. The volume occupied by the gas is decreased by pushing on the plunger, while keeping the temperature the same. Compared to the initial conditions, the helium atoms at the reduced volume will

- A. have a greater average speed.
- B. collide with the walls of the syringe more often.
- C. collide with the walls of the syringe less often.
- D. have a lower average speed.

Question 18

The **most** convenient method to produce a sample of carbon dioxide in a laboratory would be to

- A. ferment an aqueous solution of glucose.
- B. catalytically decompose an aqueous solution of hydrogen peroxide.
- C. add a dilute aqueous acid solution to a sample of solid limestone.
- D. thermally decompose a sample of solid limestone.

Question 19

At STP the volume of a 0.869 g sample of a gas was 304 mL. The molar mass of this gas would be closest to

- A. 64 g mol^{-1} .
- B. 70 g mol^{-1} .
- C. 16 g mol^{-1} .
- D. 12 g mol^{-1} .

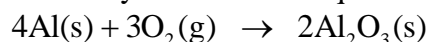
Question 20

Which one of the following gases contributes the most to the formation of acid rain as the result of industrial processes?

- A. Carbon dioxide, CO_2 .
- B. Ozone, O_3 .
- C. Carbon monoxide, CO .
- D. Sulfur dioxide, SO_2 .

Question 21

Old style photographic flash bulbs produced light using a reaction between oxygen and aluminium wire that can be described by the chemical equation



The minimum volume of pure oxygen, at SLC, that would be required to react with 0.2028 g of aluminium wire would be

- A. 184 mL
- B. 126 mL
- C. 138 mL
- D. 246 mL

Question 22

The two nitrogen containing substances that play the most significant role in soils as part of the nitrogen cycle are

- A. ammonia, NH_3 and nitrite ions, NO_2^- .
- B. ammonium, NH_4^+ and nitrate, NO_3^- ions.
- C. urea, H_2NCONH_2 and nitrogen(IV) oxide, NO_2 .
- D. ammonium ions, NH_4^+ and nitrogen(II) oxide, NO .

Question 23

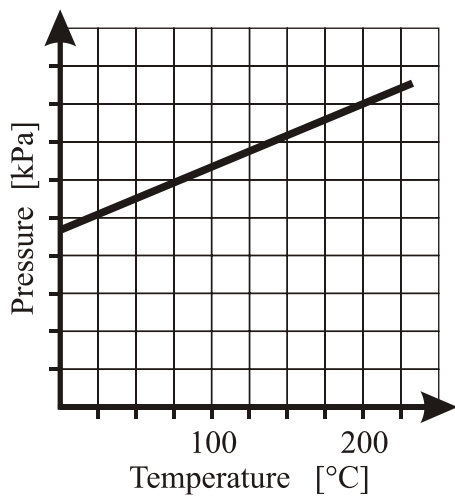
The enhanced greenhouse effect is associated with global warming because the pollutant gases in the atmosphere

- A. allow more of the reflected infrared radiation from the Earth's surface to radiate back into space.
- B. absorb some of the reflected ultraviolet radiation from the Earth's surface, reducing the amount being radiated into space.
- C. absorb some of the reflected infrared radiation from the Earth's surface, reducing the amount being radiated into space.
- D. absorb some of the ultraviolet radiation from the Sun, preventing it from reaching the Earth's surface.

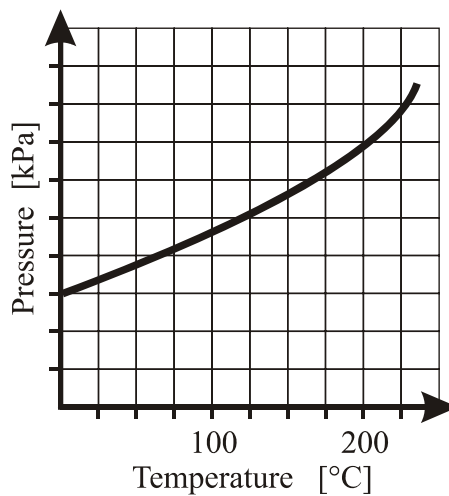
Question 24

The graph that would best describe how the pressure of a sample of an ideal gas, in a container with a fixed volume, would change with temperature is

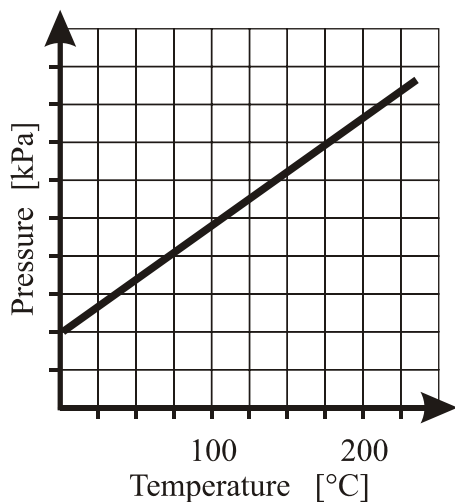
A.



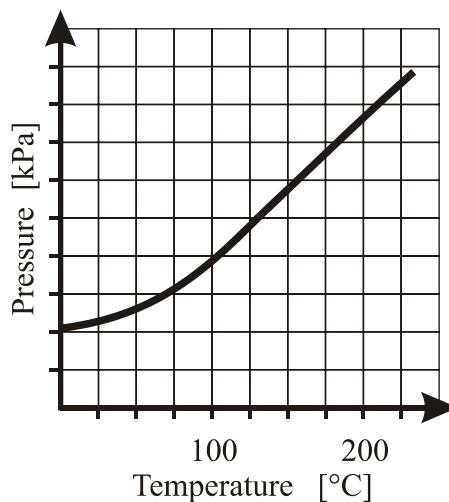
B.



C.



D.



End of Section A

VCE Chemistry 2012 Year 11 Trial Exam Unit 2

SECTION B – Short Answer Questions

(48 marks, 60 minutes)

*This section contains six questions, numbered 1 to 6.
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 (10 marks, 13 minutes)

- a. Lithium hydroxide, LiOH, is soluble in water and acts as a strong base.
- i. Write an appropriate chemical equation to describe the dissociation of lithium hydroxide in an aqueous solution.

(1 mark)

- ii. Calculate the concentration of the hydroxide ion in a 250.0 mL aqueous solution, prepared by dissolving 3.154 g of solid lithium hydroxide in deionised water.

(2 marks)

- iii. Calculate the pH of this solution at 25 °C.

(2 marks)

- b. In aqueous solutions the ethanoate ion, CH_3COO^- (aq), acts as a weak base. What is the chemical formula for the conjugate acid for this ion?

(1 mark)

- c. Write an appropriate chemical equation to describe the reaction that would occur between an aqueous solution of hydrochloric acid and solid iron(III) oxide, Fe_2O_3 .

(1 mark)

- d. Phosphoric acid, H_3PO_4 , is a weak triprotic acid.

- i. Write the chemical formulae for the two amphiprotic ions that would be present in an aqueous solution of phosphoric acid.

(1 mark)

- ii. Write an appropriate chemical equation showing one of the ions given in i. above acting as an acid.

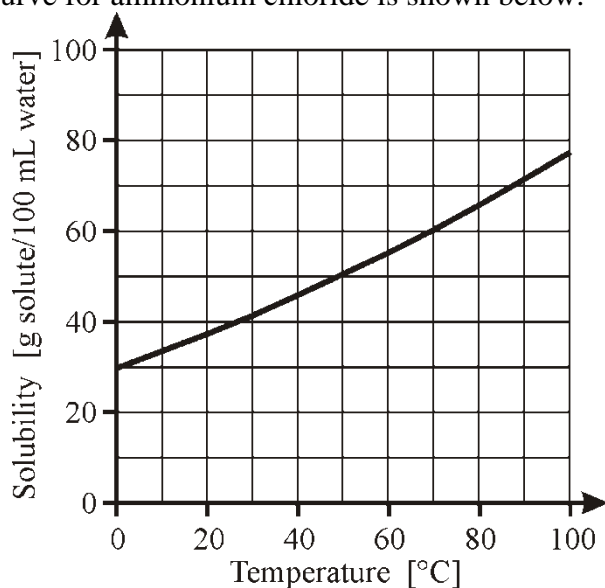
(1 mark)

- iii. Which phosphorous containing species would have the **lowest** concentration in an aqueous solution of phosphoric acid?

(1 mark)

Question 2 (10 marks, 13 minutes)

a. The solubility curve for ammonium chloride is shown below.



i. What volume of water would be required to dissolve 74.4 g of solid ammonium chloride to prepare a saturated solution at 45 °C?

(1 mark)

ii. Use the solubility curve to explain why it would not be possible to prepare an 8.0 M aqueous ammonium chloride solution by dissolving the solid in water at 20 °C.

(2 marks)

b. When aqueous solutions of potassium hydroxide and iron(III) sulfate are mixed, a brown precipitate is formed.

i. Write an appropriate chemical equation for this reaction.

(1 mark)

- ii. What mass of precipitate would be expected when excess potassium hydroxide solution is added to 25.0 mL sample of 0.0500 M iron(III) sulfate solution?

(2 marks)

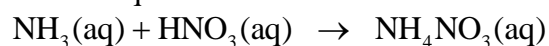
- c. When copper(II) carbonate is heated, it decomposes to form copper(II) oxide. This reaction can be described by the chemical equation



What mass of copper(II) oxide would be present after a 3.176 g sample of copper(II) carbonate was heated to constant mass in a test tube?

(2 marks)

- d. The reaction between dilute aqueous solutions of ammonia and nitric acid can be described by the chemical equation



A 20.00 mL aliquot of aqueous ammonia solution required a titre of 29.9 mL of aqueous 0.117 M nitric acid to neutralise it. What was the concentration of the ammonia solution?

(2 marks)

Question 3 (5 marks, 6 minutes)

a. In a chemical reaction an aqueous solution of bromine, $\text{Br}_2(\text{aq})$, is converted into an aqueous solution containing the bromate, $\text{BrO}_3^-(\text{aq})$, ion.

i. Write an appropriate chemical half-equation for this half-reaction.

(1 mark)

ii. What process occurs in this half-reaction?

(1 mark)

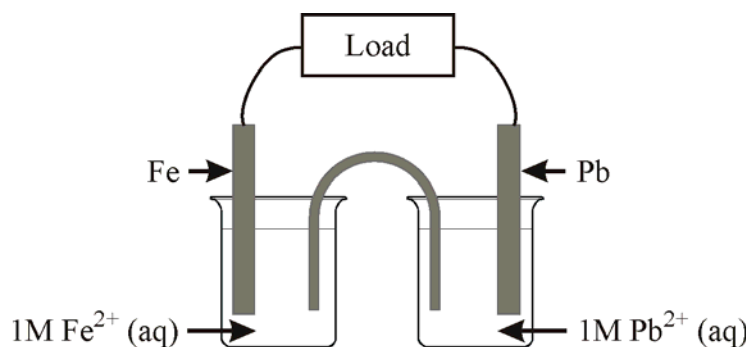
b. A galvanic cell was set up by combining the $\text{Pb}^{2+}(\text{aq})/\text{Pb}(\text{s})$ and $\text{Fe}^{2+}(\text{aq})/\text{Fe}(\text{s})$ half-cells as shown in the diagram below.

On this diagram label the following:

i. The charge on each electrode.

ii. The anode and cathode.

iii. The direction of electron flow.



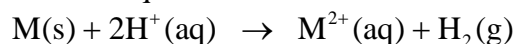
(3 marks)

Question 4 (10 marks, 13 minutes)

a. A sample of nitrogen in a fixed volume container exerted a pressure of 207 kPa at 24.5 °C. To what temperature would the gas sample have to be cooled in order for it to have a pressure of 147 kPa?

(2 marks)

- b. The reaction between Group 2 metals and dilute aqueous solutions of acid can be represented by the chemical equation



When a 1.242 g sample of a metal reacts with excess dilute aqueous acid, the volume of hydrogen gas produced at 102.7 kPa and 21.8 °C is 339 mL.

- i. Determine the number of mol of metal that reacted with the acid.

(1 mark)

- ii. Identify the metal that reacted.

(2 marks)

- c. Butane, C₄H₁₀, is a hydrocarbon that can be used as a fuel in a variety of applications.

- i. Write an appropriate chemical equation for the complete combustion of butane.

(1 mark)

- ii. Determine the volume of oxygen gas at SLC required for the complete combustion of 738 L of butane gas at SLC.

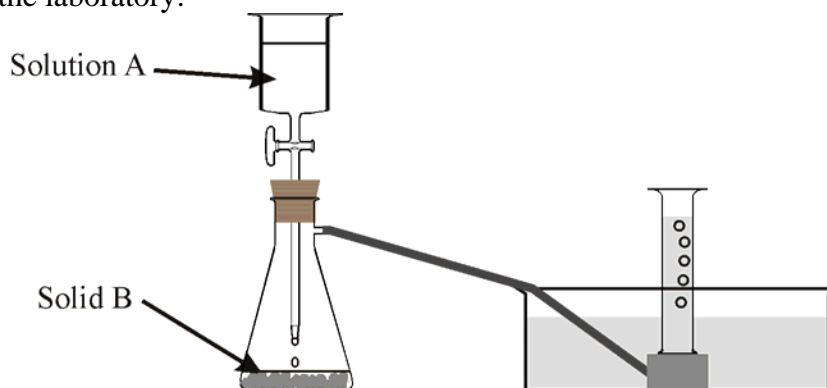
(1 mark)

- iii. Determine the mass, in kilogram, of carbon dioxide that is formed when 738 L of butane gas at SLC is completely burnt.

(3 marks)

Question 5 (7 marks, 8 minutes)

- a. The apparatus shown in the diagram below was set up to prepare a sample of oxygen gas in the laboratory.



- i. What compound would be present in Solution A?
(1 mark)
- ii. What would be the composition of Solid B?
(1 mark)
- iii. What role does Solid B perform in this reaction?
(1 mark)
- b. Commercially oxygen is prepared from air.
- i. What method is used to separate the oxygen from the other gases, principally nitrogen, argon and carbon dioxide, present in the dry air?
(1 mark)
- ii. What property of the gases does this method rely on for separating them from each other?
(1 mark)

iii. What is one industrial or commercial use of oxygen in society?

(1 mark)

c. In the lower atmosphere, what two other groups of substances react with oxygen to produce the ozone present in photochemical smog?

(1 mark)

Question 6 (6 marks, 7 minutes)

a. Plants remove carbon dioxide from the atmosphere and store it in their tissues.

i. What is the process by which plants remove carbon dioxide from the atmosphere?

(1 mark)

ii. Into what carbon containing compound do plants initially convert the carbon dioxide they remove from the atmosphere?

(1 mark)

b. Another much slower method that removes carbon dioxide from the atmosphere involves the formation of limestone deposits. How do limestone deposits form?

(1 mark)

- c. The Montreal Protocol was a significant international agreement relating to the gases in the atmosphere; it has subsequently been amended to increase its effectiveness.
- i. What atmospheric gas was the key focus of these protocols?

(1 mark)

- ii. What would have been one effect of not instituting these protocols?

(1 mark)

- iii. The manufacture and use of what substances were regulated under these protocols?

(1 mark)

End of Section B

End of Trial Exam

Suggested Answers

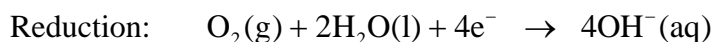
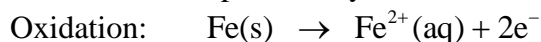
VCE Chemistry 2012 Year 11 Trial Exam Unit 2

SECTION A – Multiple Choice Answers

(1 mark per question)

- Q1 B** Since butanoic acid is a weak acid, its dissociation in solution can be represented by the chemical equation
- $$\text{C}_3\text{H}_7\text{COOH}(\text{l}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_3\text{H}_7\text{COO}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$$
- Only a **small amount of the butanoic acid will dissociate** and the concentration of the butanoate and hydrogen ions will be small compared to the concentration of the butanoic acid. Since this is an acid $[\text{H}_3\text{O}^+]$, and as a consequence $[\text{C}_3\text{H}_7\text{COO}^-]$ will be greater than 10^{-7} M.
Response B meets the requirement for a weak acid.
Responses A and C represent 100 % and 50 % dissociation therefore these do not meet the criterion for a weak acid.
Response D is too small as this would result in butanoic acid being a weaker acid than water.
- Q2 D** The reaction is described by the chemical equation
- $$3\text{Mg}(\text{s}) + \text{N}_2(\text{g}) \rightarrow \text{Mg}_3\text{N}_2(\text{s})$$
- $$M(\text{Mg}_3\text{N}_2) = 3 \times 24.3 + 2 \times 14.0 = 100.9 \text{ g mol}^{-1}$$
- $$n(\text{Mg}_3\text{N}_2) = m / M = 2.610 / 100.9 = 2.587 \times 10^{-2} \text{ mol}$$
- $$n(\text{Mg}) = 3 \times n(\text{Mg}_3\text{N}_2) = 3 \times 2.587 \times 10^{-2} = 7.760 \times 10^{-2} \text{ mol}$$
- $$m(\text{Mg}) = n \times M = 7.760 \times 10^{-2} \times 24.3 = \mathbf{1.886 \text{ g}}$$
- Q3 A** **Cornstarch can be obtained from plants**, therefore it is a **renewable resource material**. Polystyrene is manufactured from styrene which is produced from fossil fuels.
While styrene is a toxic material and a dangerous good, the main green chemistry principle exemplified is the use of a renewable resource.
- Q4 C** The concentration of the cerium(IV) ion required is 0.0100 M
- $$n(\text{Ce}^{4+}) = c \times V = 0.0100 \times (200.0/1000) = 2.00 \times 10^{-3} \text{ mol}$$
- $$M(\text{Ce}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}) = 140.1 + 2 \times 32.1 + 8 \times 16.0 + 4 \times 18.0$$
- $$= 404.3 \text{ g mol}^{-1}$$
- $$n(\text{Ce}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}) = n(\text{Ce}^{4+}) = 2.00 \times 10^{-3} \text{ mol}$$
- $$m(\text{Ce}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}) = n \times M = 2.00 \times 10^{-3} \times 404.3 = 0.809 \text{ g}$$

Q5 B The **wet corrosion of iron** in steel involves the **oxidation of iron** and the **reduction of oxygen**. These half-reactions can be described, in the first stage of the corrosion process, by chemical half-equations



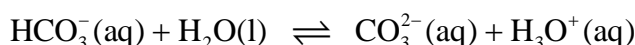
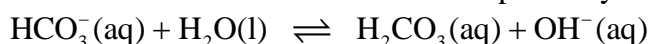
The **oxygen** for this process **comes from the air** trapped in the test tube. As the **oxygen reacts**, the amount of gas in the test tube decreases, therefore to maintain the pressure inside the test tube the same as that outside, the **water level inside the test tube rises**.

The overall wet corrosion process leading to the formation of rust, which involves the subsequent oxidation of the iron(II) ions to iron(III) ions, can be described by the chemical equation



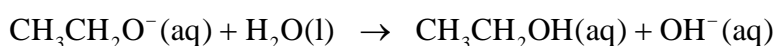
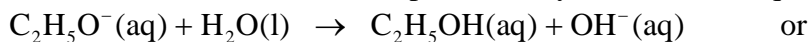
Q6 C An **amphiprotic substance is one that can act as either an acid or a base**, therefore **it must be able to either donate or accept protons**. The hydrogen carbonate ion, $\text{HCO}_3^{-}(\text{aq})$, is the only substance listed in the responses that fulfils this criterion.

The chemical equations describing the hydrogen carbonate ion acting as a weak acid or weak base with water respectively are



Carbonic acid and the ammonium ion are weak acids and the carbonate ion is a base.

Q7 A The ethoxide ion, $\text{C}_2\text{H}_5\text{O}^{-}$, completely reacts with and deprotonates water, therefore this reaction can be represented by the chemical equation



When 0.1 mol of sodium ethoxide is dissolved in water;

$$[\text{Na}^{+}] = 0.1 \text{ M}$$

Because the ethoxide reacts completely with the water then

$$[\text{OH}^{-}] = 0.1 \text{ M} \text{ and } [\text{C}_2\text{H}_5\text{OH}] = 0.1 \text{ M}$$

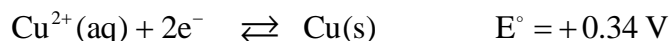
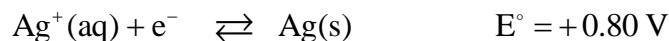
The self ionisation constant for water, $K_w = [\text{H}^{+}][\text{OH}^{-}] = 10^{-14} \text{ M}^2$

$$[\text{H}^{+}] = 10^{-14} / [\text{OH}^{-}] = 10^{-14} / 0.1 = 10^{-13} \text{ M}$$

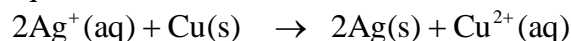
Therefore the species from those listed with the lowest concentration will be the hydrogen ion, $\text{H}^{+}(\text{aq})$.

The substance is a base, therefore the hydrogen ion concentration is always going to be less than that of the hydroxide ion and less than 10^{-7} M .

- Q8 C** Referring to the Electrochemical Series (Table 2: VCE Chemistry Data Book), the appropriate half-equations are

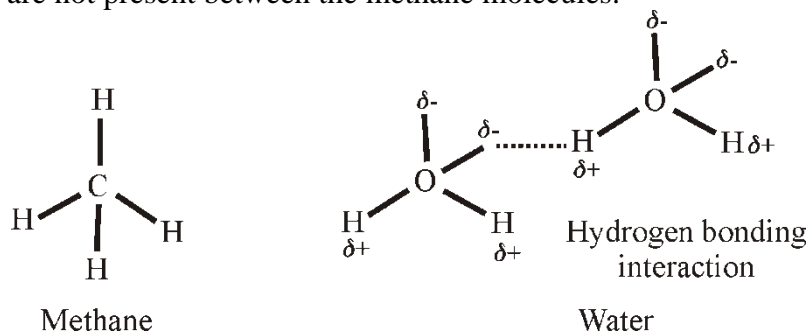


From this data it can be determined that **the silver, $\text{Ag}^+(\text{aq})$, ions are the more powerful oxidant therefore these will be reduced.** The **copper metal will act as the reductant** and be oxidised. **Reduction involves the gains of electrons** therefore the **silver ions will accept electrons.** The overall redox equation for the reaction will be



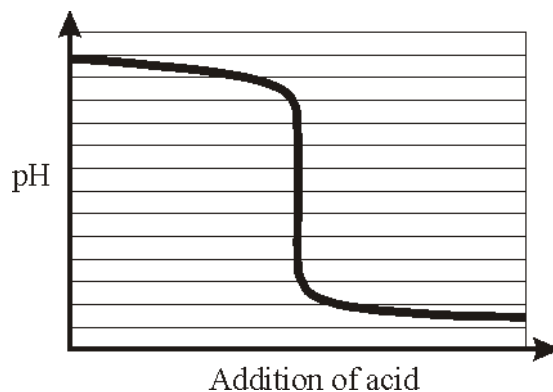
- Q9 D** The **solubility of gases in water**, in general, **decreases with increasing temperature.** The only response to meet this criterion is D. This has significant environmental implications in that the amount of oxygen dissolved in sea water will decrease as ocean temperatures rise, reducing the oxygen availability to marine life. Similarly the amount of carbon dioxide dissolved in the oceans will decrease and this will increase the amount of carbon dioxide in the atmosphere.

- Q10 C** Water and methane are molecular compounds with comparable molecular masses. The latent heat of vaporisation for water is over five times that for methane. When a molecular substance vaporises, changes from a liquid to a gas, the forces between the molecules must be broken so that the molecules can separate from one another and enter the gas state. **Water is a polar molecule whereas methane is not** due to the symmetry of the molecules. The main contribution to the increased latent heat of vaporisation for water comes from the **hydrogen bonding interactions between the water molecules** that are not present between the methane molecules.



Q11 D The chemical equation for the reaction that will occur is
 $\text{OH}^-(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$

Initially the pH of the sodium hydroxide solution will be high because there is a high concentration of hydroxide, $\text{OH}^-(\text{aq})$, ions and a low concentration of hydrogen, $\text{H}^+(\text{aq})$, ions. As the acid is added, the hydrogen ions will react with the hydroxide ions to form water. As this occurs, the concentration of the hydroxide ions decreases as the concentration of the hydrogen ions increases.



The pH is defined as

$$\text{pH} = -\log_{10}[\text{H}^+(\text{aq})]$$

If the initial $[\text{H}^+(\text{aq})] = 10^{-13} \text{ M}$ then $\text{pH} = 13$

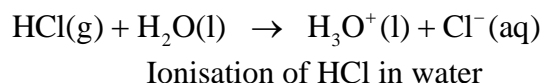
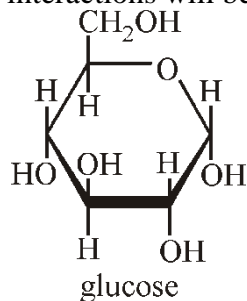
As the acid is added $[\text{H}^+(\text{aq})]$ increases, for example $[\text{H}^+(\text{aq})] = 10^{-8} \text{ M}$, then the $\text{pH} = 8$.

The graph shows how the pH of a solution will change as an aqueous hydrochloric acid solution is added to a aqueous sodium hydroxide solution. If the acid is added in excess, the whole solution will become acidic and the pH will decrease below 7.

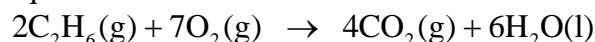
Q12 A The adage of “like dissolves like” can be applied. Water is a polar molecule, therefore it would be expected that other polar molecular compounds would be soluble and non-polar substances would be expected to be insoluble. Hexane, C_6H_{14} , is a hydrocarbon and non-polar, therefore it would be unlikely to dissolve in water. Petrol consists of hydrocarbons and is not soluble in water.

Ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, and glucose both have polar hydroxy functional groups in their structures and water will form hydrogen bonds at these sites.

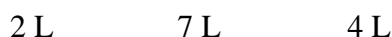
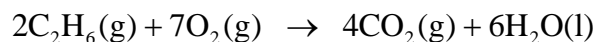
Hydrogen chloride, HCl , will ionise when dissolved in water and ion-dipole interactions will be formed between the ions and the water molecules.



Q13 B Since the conditions that the gases are being measured at are the same, SLC in this case, volume ratios can be used. The reaction is described by the chemical equation

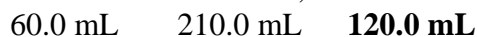


From this equation, 2 mol of ethane reacts with 7 mol of oxygen to form 4 mol of carbon dioxide. Therefore the same volume ratio will apply.



The initial mixture contains 60.0 mL of ethane and 280.0 mL of oxygen.

For 60.0 mL of ethane, then



Therefore there will be some oxygen gas in excess.

Q14 D Methane is a gas which contributes to the enhanced greenhouse effect. Most of the increased levels in the atmosphere can be associated with agricultural practices especially meat and rice production.

The burning of fossil fuels primarily contributes to the carbon dioxide levels in the atmosphere and these have had a greater impact on the enhanced greenhouse effect compared to the increase in methane levels.

Aircraft operations have been associated with increased levels of various nitrogen oxides in the atmosphere.

Q15 B The conditions are not standard so the General Gas Equation is applied. $PV = nRT$ where the units are kPa, L and K for P, V and T respectively.

$$V = 5000 \text{ L}; \quad T = 273 + 21 = 294 \text{ K}$$

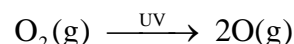
$$m(\text{SO}_2) = 350 \text{ kg} = 350 \times 1000 = 3.50 \times 10^5 \text{ g}$$

$$M(\text{SO}_2) = 32.1 + 2 \times 16.0 = 64.1 \text{ g mol}^{-1}$$

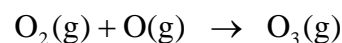
$$n(\text{SO}_2) = m/M = 3.50 \times 10^5 / 64.1 = 5.46 \times 10^3 \text{ mol}$$

$$P = \frac{nRT}{V} = \frac{5.46 \times 10^3 \times 8.31 \times 294}{5000} = \mathbf{2.7 \times 10^3 \text{ kPa}}$$

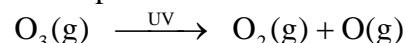
Q16 D Oxygen molecules in the stratosphere absorb high energy ultraviolet radiation from the Sun and a photochemical reaction occurs in which the oxygen molecules are broken apart into oxygen atoms.



The oxygen atoms formed in this reaction can either recombine to form oxygen molecules or react with other oxygen molecules to form ozone.



Ozone molecules present in the stratosphere will also absorb lower energy UV radiation and the resulting photochemical reaction will result in the decomposition of the ozone.



Therefore UV radiation from the Sun results in **both the formation and decomposition of ozone** in the stratosphere.

- Q17 B** The kinetic molecular theory states that the **average speed of gas particles depends on the temperature**. In this case, as the temperature remains constant, the average speed at which the helium atoms travel does not change. Since the number of helium atoms is constant, **as the volume decreases** then there will be **a greater chance of the atoms colliding with the walls of the syringe**. The rate of collisions is related to the pressure, and as the volume of a given sample of gas decreases, the pressure increases. At constant temperature, Boyle's Law, $PV = k$, is an expression of this relationship.
- Q18 C** The reactions related to responses A, C and D all result in the formation of carbon dioxide. The catalytic decomposition of aqueous hydrogen peroxide solutions produces oxygen gas.
The most convenient laboratory method is to add an acid to limestone, calcium carbonate. This reaction can be described by the chemical equation

$$\text{CaCO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Ca}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$$
The fermentation of glucose can be represented by the chemical equation

$$\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \xrightarrow{\text{Yeast}} 2\text{CH}_3\text{CH}_2\text{OH}(\text{aq}) + 2\text{CO}_2(\text{g})$$
The thermal decomposition of limestone can be represented by the chemical equation

$$\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$$
- Q19 A** The molar volume of an ideal gas at STP, $V_m = 22.4 \text{ L mol}^{-1}$
 $n(\text{gas}) = V/V_m = (304/1000)/22.4 = 1.36 \times 10^{-2} \text{ mol}$
 $M(\text{gas}) = m/n = 0.869/1.36 \times 10^{-2} = \mathbf{64 \text{ g mol}^{-1}}$
- Q20 D** Carbon monoxide and ozone are neutral oxides and do not contribute to the acidity of rainfall. Carbon dioxide and **sulfur dioxide** will both dissolve in water to form weakly acidic solutions, carbonic and sulfurous acid respectively.

$$\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{CO}_3(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$$

$$\text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{SO}_3(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HSO}_3^-(\text{aq})$$
Additionally, sulfur dioxide can be oxidised in the atmosphere to form sulfur trioxide, SO_3 , which will then dissolve to yield sulfuric acid, H_2SO_4 , which is a strong acid.

$$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$$

$$\text{SO}_3(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{HSO}_4^-(\text{aq})$$
The oxides of sulfur are formed as the result of burning fossil fuels and contribute more to the formation of acid rain resulting from industrial processes than the increased levels of carbon dioxide, because both sulfur containing acids are stronger than carbonic acid.

- Q21 C** The reaction is described by the chemical equation

$$4\text{Al(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Al}_2\text{O}_3\text{(s)}$$

$$n(\text{Al}) = m/M = 0.2028/27.0 = 7.511 \times 10^{-3} \text{ mol}$$

$$n(\text{O}_2) = \frac{3}{4}n(\text{Al}) = \frac{3}{4} \times 7.511 \times 10^{-3} = 5.633 \times 10^{-3} \text{ mol}$$

$$V_m(\text{SLC}) = 24.5 \text{ L mol}^{-1}$$

$$V(\text{O}_2) = n(\text{O}_2) \times V_m = 5.633 \times 10^{-3} \times 24.5 = 1.38 \times 10^{-1} \text{ L} = \mathbf{138 \text{ mL}}$$
- Q22 B** In soils the most significant roles in the nitrogen cycle involve **ammonium, NH_4^+ and nitrate, NO_3^- , ions**. These are absorbed through the roots by plants and used to synthesise proteins. Bacteria in the soil can oxidise ammonium ions to nitrate ions, reduce nitrate ions to nitrogen and convert nitrogen compounds that are excreted and/or the result of decay into ammonium ions. Nitrogen-fixing bacteria, found in the root nodules of certain plants, convert nitrogen from the atmosphere into ammonium ions.
- Q23 C** The enhanced greenhouse effect is due to increased levels of various pollutant gases. Like the greenhouse effect, these gases absorb infrared radiation that is reflected from the Earth's surface, preventing it from being radiated into space. This causes the temperature of the atmosphere to increase.
- Q24 A** The pressure-temperature relationship is often ascribed to Gay-Lussac (1809), however he investigated the volume-temperature relationship. From the general gas equation, $PV = nRT$, if volume and the amount of gas are kept constant, then $k = nR/V$
 $P = kT$, where temperature, T , is in Kelvin or
 $P = k(t + 273)$, where temperature, t , is in degrees Celsius.
 This is a linear relationship between pressure and temperature, therefore only responses A and C meet this criterion.
 Response C is incorrect as extrapolation of the relationship line would give a zero pressure at a temperature of around $-75 \text{ }^\circ\text{C}$ (about 200 K) not 0 K ($-273 \text{ }^\circ\text{C}$) as expected.

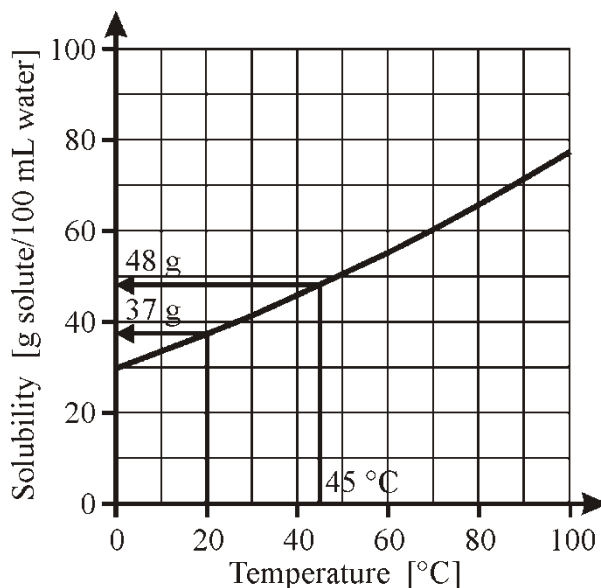
SECTION B – Short Answer (Answers)

Question 1 (10 marks, 13 minutes)

- a. i. $\text{LiOH(s)} \rightarrow \text{Li}^{\text{+}}(\text{aq}) + \text{OH}^{\text{-}}(\text{aq})$ (1 mark).
- ii. $M(\text{LiOH}) = 6.9 + 16.0 + 1.0 = 23.9 \text{ g mol}^{-1}$
 $n(\text{LiOH}) = m / M = 3.154 / 23.9 = 1.32 \times 10^{-1} \text{ mol}$ (1 mark).
 $c(\text{LiOH}) = n / V = 1.32 \times 10^{-1} / (250.0 / 1000) = 5.28 \times 10^{-1} \text{ M}$
 $c(\text{OH}^{\text{-}}) = c(\text{LiOH}) = 5.28 \times 10^{-1} \text{ M}$ (1 mark).
- iii. From Table 3: VCE Chemistry Data Book the self ionisation constant for water
 $K_{\text{w}} = [\text{H}^{\text{+}}][\text{OH}^{\text{-}}] = 1.00 \times 10^{-14} \text{ M}^2$
 $[\text{OH}^{\text{-}}] = 5.28 \times 10^{-1} \text{ M}$
 $[\text{H}^{\text{+}}] = 1.00 \times 10^{-14} / 5.28 \times 10^{-1} = 1.89 \times 10^{-14} \text{ M}$ (1 mark).
 $\text{pH} = -\log_{10}[\text{H}^{\text{+}}] = -\log_{10}(1.08 \times 10^{-14}) = 13.7$ (1 mark).
- b. The ethanoate is a weak base, therefore it will accept a proton to form the conjugate acid, ethanoic acid, $\text{CH}_3\text{COOH(aq)}$ (1 mark).
The chemical equation for this reaction in water would be
 $\text{CH}_3\text{COO}^{\text{-}}(\text{aq}) + \text{H}_2\text{O(l)} \rightleftharpoons \text{CH}_3\text{COOH(aq)} + \text{OH}^{\text{-}}(\text{aq})$
- c. Either a full or ionic equation would be appropriate (1 mark).
 $\text{Fe}_2\text{O}_3(\text{s}) + 6\text{HCl(aq)} \rightarrow 2\text{FeCl}_3(\text{aq}) + 3\text{H}_2\text{O(l)}$
 $\text{Fe}_2\text{O}_3(\text{s}) + 6\text{H}^{\text{+}}(\text{aq}) \rightarrow 2\text{Fe}^{3+}(\text{aq}) + 3\text{H}_2\text{O(l)}$
- d. i. Phosphoric acid, H_3PO_4 , is a triprotic acid, meaning that it can release three hydrogen ions when it ionises or reacts with bases. There are two ions that can be formed when phosphoric acid ionises that are amphiprotic, can act as either an acid or a base. In an aqueous solution these ions are; dihydrogen phosphate, $\text{H}_2\text{PO}_4^{\text{-}}(\text{aq})$, and hydrogen phosphate, $\text{HPO}_4^{2-}(\text{aq})$ (1 mark).
- ii. [1 mark for a correct chemical equation]
Dihydrogen phosphate ion:
 $\text{H}_2\text{PO}_4^{\text{-}}(\text{aq}) + \text{H}_2\text{O(l)} \rightleftharpoons \text{HPO}_4^{2-}(\text{aq}) + \text{H}_3\text{O}^{\text{+}}(\text{aq})$ or
 $\text{H}_2\text{PO}_4^{\text{-}}(\text{aq}) + \text{OH}^{\text{-}}(\text{aq}) \rightleftharpoons \text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O(l)}$
Hydrogen phosphate ion:
 $\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O(l)} \rightleftharpoons \text{PO}_4^{3-}(\text{aq}) + \text{H}_3\text{O}^{\text{+}}(\text{aq})$ or
 $\text{HPO}_4^{2-}(\text{aq}) + \text{OH}^{\text{-}}(\text{aq}) \rightleftharpoons \text{PO}_4^{3-}(\text{aq}) + \text{H}_2\text{O(l)}$
- iii. Since phosphoric acid is a weak acid then the ionisation of the acid is described by the three chemical equations
 $\text{H}_3\text{PO}_4(\text{aq}) + \text{H}_2\text{O(l)} \rightleftharpoons \text{H}_2\text{PO}_4^{\text{-}}(\text{aq}) + \text{H}_3\text{O}^{\text{+}}(\text{aq})$
 $\text{H}_2\text{PO}_4^{\text{-}}(\text{aq}) + \text{H}_2\text{O(l)} \rightleftharpoons \text{HPO}_4^{2-}(\text{aq}) + \text{H}_3\text{O}^{\text{+}}(\text{aq})$
 $\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O(l)} \rightleftharpoons \text{PO}_4^{3-}(\text{aq}) + \text{H}_3\text{O}^{\text{+}}(\text{aq})$
As each reaction only produces a small amount of the product then the final reaction would produce the least, as the amount that it starts with is less than the previous. Therefore the **phosphate, $\text{PO}_4^{3-}(\text{aq})$, ion** would have the lowest concentration in an aqueous solution of phosphoric acid (1 mark).
In a 1.0 M aqueous phosphoric acid solution the concentrations of the various species present are:
 $[\text{H}_3\text{PO}_4] = 0.92 \text{ M}$, $[\text{H}_2\text{PO}_4^{\text{-}}] = 8.1 \times 10^{-2} \text{ M}$, $[\text{HPO}_4^{2-}] = 6.3 \times 10^{-8} \text{ M}$,
 $[\text{PO}_4^{3-}] = 3.3 \times 10^{-18} \text{ M}$, $[\text{H}^{\text{+}}] = 8.1 \times 10^{-2} \text{ M}$ and $\text{pH} = 1.1$

Question 2 (10 marks, 13 minutes)

- a. i. From the solubility curve the solubility of ammonium chloride at 45 °C is 48 g/100mL.



A saturated solution is one that any more solute cannot dissolve in the solvent.

$$V(\text{water required}) = (74.4/48) \times 100 = \mathbf{155 \text{ mL} \text{ (1 mark)}}$$

- ii. From the solubility curve the solubility of ammonium chloride at 20 °C is 37 g/100mL.

$$M(\text{NH}_4\text{Cl}) = 14.0 + 4 \times 1.0 + 35.5 = 53.5 \text{ g mol}^{-1}$$

For 100 mL of an 8.0 M aqueous solution

$$n(\text{NH}_4\text{Cl}) = c \times V = 8.0 \times (100/1000) = 0.8 \text{ mol}$$

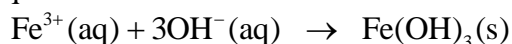
$$m(\text{NH}_4\text{Cl}) = n \times M = 0.8 \times 53.5 = 42.8 \text{ g (1 mark)}$$

Since the **mass of solute required is greater than the solubility of the solute at 20 °C** then a solution with a concentration of 8.0 M cannot be prepared by dissolving the solute in water at that temperature **(1 mark)**.

To have an aqueous solution with a concentration of 8.0 M at 20 °C would require the solution to be supersaturated.

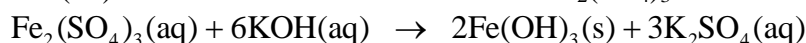
- b. i. All common potassium (Group 1 element) compounds are soluble in water, therefore the precipitate must be iron(III) hydroxide, Fe(OH)₃.
Either an ionic or full equation would be acceptable **(1 mark)**.

Ionic Equation:



Full Equation:

Iron(III) sulfate has the chemical formula Fe₂(SO₄)₃



- ii. The precipitate is iron(III) hydroxide, Fe(OH)₃.

The formula for iron(III) sulfate is Fe₂(SO₄)₃

$$n(\text{Fe}_2(\text{SO}_4)_3) = c \times V = 0.0500 \times (25.0/1000) = 1.25 \times 10^{-3} \text{ mol}$$

$$n(\text{Fe}^{3+}) = 2n(\text{Fe}_2(\text{SO}_4)_3) = 2 \times 1.25 \times 10^{-3} = 2.50 \times 10^{-3} \text{ mol}$$

$$n(\text{Fe}(\text{OH})_3) = n(\text{Fe}^{3+}) = 2.50 \times 10^{-3} \text{ mol (1 mark)}$$

$$M(\text{Fe}(\text{OH})_3) = 55.9 + 3 \times (16.0 + 1.0) = 106.9 \text{ g mol}^{-1}$$

$$m(\text{Fe}(\text{OH})_3) = n \times M = 2.5 \times 10^{-3} \times 106.9 = \mathbf{0.267 \text{ g (1 mark)}}$$

Alternatively if using the full equation

$$n(\text{Fe}_2(\text{SO}_4)_3) = c \times V = 0.0500 \times (25.0/1000) = 1.25 \times 10^{-3} \text{ mol}$$

$$n(\text{Fe}(\text{OH})_3) = 2n(\text{Fe}_2(\text{SO}_4)_3) = 2 \times 1.25 \times 10^{-3} = 2.50 \times 10^{-3} \text{ mol †}$$

$$M(\text{Fe}(\text{OH})_3) = 55.9 + 3 \times (16.0 + 1.0) = 106.9 \text{ g mol}^{-1}$$

$$m(\text{Fe}(\text{OH})_3) = n \times M = 2.5 \times 10^{-3} \times 106.9 = \mathbf{0.267 \text{ g †}}$$

† Indicates where mark would be allocated using this answer

- c. The chemical equation for the reaction is

$$\text{CuCO}_3(\text{s}) \rightarrow \text{CuO}(\text{s}) + \text{CO}_2(\text{g})$$

$$M(\text{CuCO}_3) = 63.6 + 12.0 + 3 \times 16.0 = 123.6 \text{ g mol}^{-1}$$

$$M(\text{CuO}) = 63.6 + 16.0 = 79.6 \text{ g mol}^{-1}$$

$$n(\text{CuCO}_3) = m/M = 3.176/123.6 = 2.57 \times 10^{-2} \text{ mol (1 mark).}$$

$$n(\text{CuO}) = n(\text{CuCO}_3) = 2.57 \times 10^{-2} \text{ mol}$$

$$m(\text{CuO}) = n \times M = 2.57 \times 10^{-2} \times 79.6 = \mathbf{2.05 \text{ g (1 mark).}}$$
- d. The chemical equation for the titration is

$$\text{NH}_3(\text{aq}) + \text{HNO}_3(\text{aq}) \rightarrow \text{NH}_4\text{NO}_3(\text{aq})$$

$$n(\text{HNO}_3) = c \times V = 0.117 \times (29.9/1000) = 3.50 \times 10^{-3} \text{ mol (1 mark).}$$

$$n(\text{NH}_3) = n(\text{HNO}_3) = 3.5 \times 10^{-3} \text{ mol}$$

$$c(\text{NH}_3) = n/V = 3.5 \times 10^{-3} / (20.0/1000) = \mathbf{0.175 \text{ M (1 mark).}}$$

Question 3 (5 marks, 6 minutes)

- a. i. Bromine, $\text{Br}_2(\text{aq})$, is converted into the bromate, $\text{BrO}_3^-(\text{aq})$, ion in the reaction. The half-equation can be developed using the following steps.
- Identify the reactants and products.

$$\text{Br}_2 \rightarrow \text{BrO}_3^-$$
 - Balance the equation for all atoms other than hydrogen and oxygen.

$$\text{Br}_2 \rightarrow 2\text{BrO}_3^-$$
 - Balance oxygen atoms by adding water.

$$\text{Br}_2 + 6\text{H}_2\text{O} \rightarrow 2\text{BrO}_3^-$$
 - Balance hydrogen atoms by adding hydrogen ions.

$$\text{Br}_2 + 6\text{H}_2\text{O} \rightarrow 2\text{BrO}_3^- + 12\text{H}^+$$
 - Balance the charge by adding electrons.

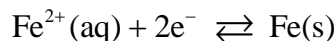
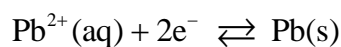
$$\text{Br}_2 + 6\text{H}_2\text{O} \rightarrow 2\text{BrO}_3^- + 12\text{H}^+ + 10\text{e}^-$$
 - Add appropriate state symbols

$$\text{Br}_2(\text{aq}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{BrO}_3^-(\text{aq}) + 12\text{H}^+(\text{aq}) + 10\text{e}^- \text{ (1 mark).}$$
- ii. Since this process is releasing electrons then it is an **oxidation reaction**.
(1 mark).
The oxidation number for bromine is changing from 0 to +5. This indicates the loss of electrons therefore oxidation.
Oxidation number for an element is zero.
In ions/compounds the oxidation number for oxygen is -2 unless otherwise stated. The sum of the oxidation numbers must equal the charge on an ion.
For the bromate ion.

$$ON(\text{Br}) + 3ON(\text{O}) = ON(\text{Br}) + 3 \times (-2) = -1$$

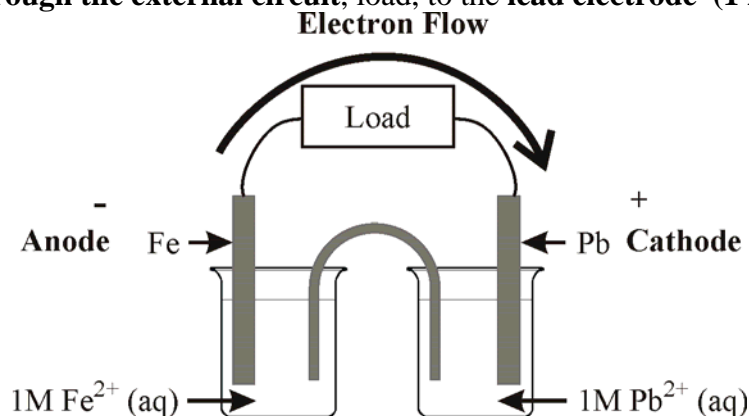
$$ON(\text{Br}) = +5$$

- b. In this galvanic cell the oxidant and reductant can be determined using the electrochemical series (Table 2: VCE Chemistry Data Book).
The two half-equations from the electrochemical series in order from the stronger oxidant are:



Therefore the lead(II), $\text{Pb}^{2+}(\text{aq})$, ions are the stronger oxidant and will be reduced while the iron is being oxidised.

- Oxidation involves the loss of electrons** therefore in a **galvanic cell the electrode where oxidation takes place, the iron electrode, will have a negative charge** while the electrode where reduction occurs, the lead electrode, will have a positive charge (1 mark).
- In electrochemical cells **oxidation always occurs at the anode, the iron electrode, and reduction at the cathode, the lead electrode.** (1 mark).
- The electrons are being **released at the iron electrode** therefore must **flow through the external circuit, load, to the lead electrode** (1 mark).



Question 4 (10 marks, 13 minutes)

- a. This involves changing the conditions for a given sample of gas, therefore the combined gas equation can be used.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad \text{since the volume is constant this becomes} \quad \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

The **temperature must be in Kelvin**

$$T_1 = 24.5 + 273 = 297.5 \text{ K}$$

$$\frac{207}{297.5} = \frac{147}{T_2} \Rightarrow 0.696 = \frac{147}{T_2} \quad \text{(1 mark)}$$

$$T_2 = \frac{147}{0.696} = \mathbf{211.3 \text{ K (1 mark) (or } -61.7 \text{ }^\circ\text{C)}$$

- b. i. $P = 102.7 \text{ kPa}$ $V = 339/1000 = 0.339 \text{ L}$ $T = 21.8 + 273 = 294.8 \text{ K}$
Using the General Gas Equation, $PV = nRT$, to determine the number of mol of hydrogen formed.

$$n(\text{H}_2) = \frac{PV}{RT} = \frac{102.7 \times 0.339}{8.31 \times 294.8} = 1.42 \times 10^{-2} \text{ mol}$$

From the chemical equation the mol ratio of metal:hydrogen is 1:1

$$n(\text{M}) = n(\text{H}_2) = \mathbf{1.42 \times 10^{-2} \text{ mol (1 mark).}$$

- ii. $M(M) = m/n = 1.242 / 1.42 \times 10^{-2} = 87.5 \text{ g mol}^{-1}$ **(1 mark)**.
Using the relative atomic masses from the Periodic Table (Table 1: VCE Chemistry Data Book) for Group 2 metals, this value is closest to that for **strontium (1 mark)**.
- c. i. The products of the complete combustion of a hydrocarbon are carbon dioxide and water. The chemical equation for the complete combustion of a hydrocarbon can be determined using the following steps **(1 mark)**.
- Write down the reactants and products of the reaction.
 $\text{C}_4\text{H}_{10}(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
 - Balance the number of carbon atoms in the chemical equation.
 $\text{C}_4\text{H}_{10}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
 - Balance the number of hydrogen atoms in the chemical equation.
 $\text{C}_4\text{H}_{10}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 5\text{H}_2\text{O}(\text{l})$
 - Balance the number of oxygen atoms in the chemical equation remembering that the reactant is O_2 .
Products: $4 \times 2 + 5 = 13$
 O_2 molecules required = $13/2$
 $\text{C}_4\text{H}_{10}(\text{g}) + \frac{13}{2}\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 5\text{H}_2\text{O}(\text{l})$
The chemical equation can be left at this stage for combustion reactions as long as the correct state symbols have been included.
Alternatively the coefficients can be multiplied by 2.
 $2\text{C}_4\text{H}_{10}(\text{g}) + 13\text{O}_2(\text{g}) \rightarrow 8\text{CO}_2(\text{g}) + 10\text{H}_2\text{O}(\text{l})$
- ii. From the chemical equation the mole ratio of butane:oxygen is 2:13 or 1: $13/2$. Since both gases are at SLC then the volume ratio is equivalent to the molar ratio.
 $V(\text{O}_2) = 13/2 V(\text{C}_4\text{H}_{10}) = 13/2 \times 738 = \mathbf{4800 \text{ L (1 mark)}}$.
- iii. Using the chemical equation the molar ratio of butane:carbon dioxide is 1:4. At SLC
 $V(\text{CO}_2) = 4V(\text{C}_4\text{H}_{10}) = 4 \times 738 = 2952 \text{ L (1 mark)}$.
 $n(\text{CO}_2) = V(\text{CO}_2)/V_m = 2952/24.5 = 120.5 \text{ mol (1 mark)}$.
 $M(\text{CO}_2) = 12.0 + 2 \times 16.0 = 44.0 \text{ g mol}^{-1}$
 $m(\text{CO}_2) = n(\text{CO}_2) \times M(\text{CO}_2) = 120.5 \times 44.0 = 5302 \text{ g} = \mathbf{5.30 \text{ kg (1 mark)}}$.

Question 5 (7 marks, 8 minutes)

- a. The laboratory preparation of oxygen gas is most commonly carried out by catalytically decomposing an aqueous solution of hydrogen peroxide.
 $2\text{H}_2\text{O}_2(\text{aq}) \xrightarrow{\text{MnO}_2(\text{s})} \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
- Hydrogen peroxide, $\text{H}_2\text{O}_2(\text{aq})$ (1 mark).**
 - The most commonly used catalyst is **manganese(IV) oxide, MnO_2 (1 mark)**.
Potassium permanganate, KMnO_4 , can be used in this reaction, however it is not a completely catalytic reaction and the permanganate ion acts as an oxidant and is reduced. In this process manganese(IV) oxide can be produced under certain conditions and this will then act as a catalyst in the reaction.
 - The **manganese(IV) oxide acts as a catalyst** and speeds up the decomposition of the hydrogen peroxide solution **(1 mark)**.

- b. i. The four principal gases present in dry air are shown in the table below together with their boiling temperatures. The industrial production of oxygen involves the **fractional distillation** of liquid air **(1 mark)**.

Gas	Volume %	Boiling Temperature
Nitrogen (N ₂)	78.084%	-196 °C
Oxygen (O ₂)	20.946%	-183 °C
Argon (Ar)	0.9340%	-186 °C
Carbon dioxide (CO ₂)	0.039%	-78 °C

- ii. The property that fractional distillation relies on for separating the gases is the **boiling temperature** of the substance **(1 mark)**.
- iii. Possible answers include: **(1 mark)**.
 Medical applications – the use of oxygen to treat patients with respiratory problems.
 The production of steel, where the basic oxygen steelmaking process uses oxygen to remove impurities and lower the carbon content in pig iron.
 Treatment of water, where ozone is generated and used to kill bacteria.
 Rocket fuels, where liquid oxygen is used as the oxidant for the fuel such as hydrogen or a hydrocarbon.
 The production of other chemicals such as sulfuric acid.
- c. Photochemical smog contains ozone, peroxyacetyl nitrate, PAN, and aldehydes that are produced in complex photochemical reactions between oxygen and **oxides of nitrogen** and **unburnt hydrocarbons** **(1 mark)**. The oxides of nitrogen, NO_x, and the unburnt hydrocarbons can be formed in car engines.

Question 6 (6 marks, 7 minutes)

- a. i. Plants remove carbon dioxide from the atmosphere through the **photosynthesis** process **(1 mark)**. The reaction that occurs can be described by the chemical equation
- $$6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{g})$$
- ii. Photosynthesis initially produces **glucose** **(1 mark)**. This glucose can be converted into starch for later use by the plant or into cellulose which is used to build plant cell walls.
- b. Limestone, calcium carbonate, CaCO₃, is formed from the **corals and the skeletons of dead marine animals** over long durations **(1 mark)**.
- c. i. The Montreal Protocol and its subsequent amendments related to the amount of ozone in the stratosphere **(1 mark)**.
- ii. Possible answers include: **(1 mark)**.
 Decreased levels of ozone in the upper atmosphere would have lead to more UV radiation reaching the surface of the Earth.
 Increased occurrence of skin cancer in humans and other animals as a result of the increased UV radiation reaching the Earth's surface.
 Decreased plant crop production as a result of damage to plants by the higher levels of UV radiation reaching the Earth's surface.
- iii. The protocols removed the use of **chlorofluorocarbons, CFCs**, as aerosols and their use in the production of other products **(1 mark)**. *Halons or ozone depleting agents could also be answers.*

End of Suggested Answers