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

During a chemical reaction in a sealed vessel of fixed volume

A. the temperature of the vessel is always constant.
B. the pressure of the gaseous substances in the vessel is always constant.
C. the total number of moles of reactants and products is always constant.
D. the total number of atoms is always constant.

Question 2

Which of the following pairs of aqueous solutions would result in the formation of a precipitate?

A. K_2SO_4 and $NaNO_3$
B. K_2SO_4 and NaCl
C. Na_2SO_4 and $Ba(OH)_2$
D. NaOH and KNO_3

Question 3

Which one of the following contains only substances which are substantially soluble in water?

A. CH_3CH_2OH, $NaNO_3$, NH_3
B. NaOH, $MgCl_2$, C_5H_{12}
C. $CaCO_3$, C_8H_{18}, HF
D. $(NH_4)_2SO_4$, CH_4, NaCl

Question 4

An aqueous solution of sodium chloride has a concentration of 0.100 M. The statement which would best describe this could be?

A. 5.85 g of sodium chloride added to 1.00 L of distilled water.
B. 0.100 mol of sodium chloride molecules per 1.00 L of solution.
C. 5.85 g of sodium chloride per 1.00 L of solution.
D. 0.100 mol of sodium ions added to 1.00 L of distilled water.

Question 5

The final concentration of chloride ions in a solution prepared by adding 100 mL of 0.500 M aluminium chloride, $AlCl_3$ to 100 mL of 0.500 M sodium chloride, NaCl is

A. 0.50 M
B. 1.00 M
C. 1.50 M
D. 2.00 M

Question 6

Hydrogen and chlorine react completely according to the equation given below:

$$H_2(g) + Cl_2(g) \rightarrow 2\,HCl(g)$$

3 mole of H_2 and 2 mole of Cl_2 are placed in a vessel which is sealed and heated. When reaction is complete the vessel will contain:

A. 5 mole of HCl
B. 6 mole of HCl and 1 mole of Cl_2
C. 4 mole of HCl and 1 mole of Cl_2
D. 4 mole of HCl and 1 mole of H_2

Question 7

Lemon juice has a pH of 3.0. If 1.0 mL of the juice is diluted by adding enough water to increase the total volume to 100 mL, the pH of the resulting solution would be closest to

A. 2.0
B. 4.0
C. 5.0
D. 7.0

Question 8

When considering the chemical properties of acids, which one or more of the following statements are correct?

I they react with bases to produce salts;

II they react with carbonates to produce carbon dioxide;

III they react with hydrogen carbonates to produce carbon dioxide;

IV they react with active metals to produce hydrogen gas.

A. I only

B. I and II only

C. I, II and III only

D. All statements I, II, III and IV.

Question 9

An antacid is known to contain 400 mg of magnesium hydroxide, $Mg(OH)_2$ ($M = 58.3$ g mol^{-1}), per 10.0 mL. The amount of hydroxide ions, in mol, in 1.0 L of the antacid would be closest to

A. 1.37×10^{-3}

B. 1.37×10^{-2}

C. 0.137

D. 1.37

Question 10

A coal-burning power station burns coal which contains 1.0 % sulfur by mass. If the power station burns 5600 tonnes of coal a day, the mass, in tonnes, of sulfur dioxide released into the air each day would be closest to

A. 110

B. 150

C. 180

D. 200

Question 11

Which one of the following statements about an aqueous solution of the weak acid hydrogen sulfide, H_2S, is correct?

A. Large numbers of non-ionised H_2S molecules are present in the solution.

B. The hydrogen sulfide is mostly converted into H_3O^+ ions.

C. All the solute is present as H_2S molecules.

D. The hydrogen sulfide is mostly ionised to H^+ and S^{2-}.

Question 12

A sample of vinegar containing 0.100 mol of ethanoic acid, CH_3COOH, has a concentration of 0.125 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 13

If 64 g of oxygen gas, O_2, occupies 50.0 L at a certain temperature and pressure, then 144 g of ozone gas, O_3, at the same temperature and pressure, would occupy

A. 33.3 L

B. 50.0 L

C. 75.0 L

D. 100 L

Question 14

60 mL of O_2 gas and 20.0 mL of NH_3 gas are mixed in a sealed vessel and reaction occurs according to the equation:

$$3O_2(g) + 4NH_3(g) \rightarrow 2N_2(g) + 6H_2O(g)$$

After the reaction, the gaseous components were separated, without changing the temperature or pressure. The volume of N_2 gas produced was

A. 10.0 mL

B. 13.3 mL

C. 20.0 mL

D. 30.0 mL

Question 15

In order to double the pressure exerted by a 2.0 L sample of gas inside a steel syringe, initially at 17°C, one could:

A. increase the volume of the syringe to 4.0 L, without changing the temperature.

B. increase the temperature of the contents to 34 °C, without changing the volume.

C. increase the temperature of the contents to 307 K, without changing the volume.

D. increase the temperature of the contents to 580 K, without changing the volume.

Question 16

When potassium is added to 0.10 M HCl, hydrogen gas is rapidly released. In the reaction producing hydrogen gas, potassium is behaving as:

A. a reductant.

B. an oxidant.

C. a base.

D. an acid.

Question 17

Which of the following pairs of substances when mixed, will react spontaneously?

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

Which of the following is correct for the oxidation reaction in an electrochemical cell made up of an Fe^{2+} / Fe half cell and an Sn^{2+} / Sn half cell?

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

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

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

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

Question 19

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 20

The substance $Na_2CO_3.10H_2O$ is a useful substance in a chemistry laboratory. If 0.100 mol of $Na_2CO_3.10H_2O$ was dissolved in water to make one litre of solution, the solution would be

A. strongly acidic

B. weakly acidic

C. neutral

D. basic

END OF SECTION A

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 for 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 key step in the production of nitric acid is the production of nitrogen (II) oxide, NO, represented by following equation

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

a. What mass, in gram, of ammonia would be needed to produce 1.00 kg of nitrogen(II) oxide?

4 marks

b. What amount of oxygen, in mol, would be needed if 1.00 kg of steam was generated?

3 marks

Total 7 marks

Question 2

When aqueous solutions of sodium hydroxide (NaOH) and iron(III) chloride ($FeCl_3$) react, a precipitate of iron(III) hydroxide is formed.

a. Write a balanced equation for the precipitation reaction.

2 marks

b. If 9 mL of 1.0 M NaOH(aq) is added to 10.0 mL of 1.0 M $FeCl_3$(aq),

i. Which chemical is in excess and by how many mol?

ii. What mass of iron(III) hydroxide would be precipitated?

5 marks
Total 7 marks

Question 3

A student takes 250 mL of 0.0500 M H_2SO_4(aq) from a container.

a. Determine the pH of the acidic solution?

2 marks

b. Calculate the number of mol of H^+ in the solution.

2 marks

c. The solution is then diluted to 1.00 Litre by the addition of distilled water. Calculate the pH of the diluted solution.

2 marks

d. Calculate the volume of 0.10 M NaOH needed to neutralize the solution.

2 marks
Total 8 marks

Question 4

A balloon is inflated with 16.0 g of oxygen gas at 280 K. If the temperature rises to 320 K and the pressure remains constant, what mass of oxygen must be released in order for the balloon to stay the same size?

Total 4 marks

Question 5

Write a balanced overall equation for each of the following. States are not required.

a. respiration

2 marks

b. carbon dioxide and limewater (a solution of calcium hydroxide

2 marks

c. sulfuric acid and barium hydroxide, $Ba(OH)_2$ solutions are mixed

2 marks

d. hydrochloric acid and solid magnesium carbonate, $MgCO_3$

2 marks

e. fixing of nitrogen gas to form nitrogen monoxide or nitrogen (II) oxide.

2 marks

f. production of oxygen gas from the catalytic decomposition of hydrogen peroxide, H_2O_2.

2 marks

g. the combustion of butane, C_4H_{10} in excess oxygen :

2 marks
Total 14 marks

Question 6

a. Carbonic acid, H_2CO_3 is referred to as a weak, diprotic acid. It is formed when CO_2 dissolves and then ionises in water.

i. Write the two equations which show that carbonic acid is a diprotic acid in water.

ii. Explain why carbonic acid is regarded as a weak acid.

3 marks

b. A pressurized bottle holds 500 mL of an aqueous solution containing 2.20 g of CO_2. The bottle is heated to 40°C and then opened to the atmosphere so that all the CO_2 in the solution escapes as CO_2 gas. Calculate, in litres, the volume of CO_2 that would be evolved at 1.00 atm pressure and 40°C.

3 marks

c. Write the symbols for each of the following:

i. the conjugate base of H_2O _____

ii. the conjugate acid of NH_3 _____

2 marks

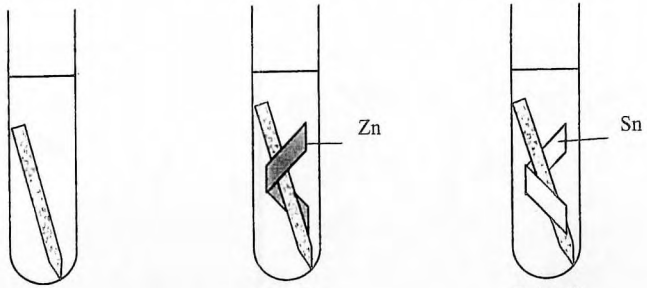
d. Calculate the pH of 0.00500 M $Ba(OH)_2$ (aq).

2 marks

Total 10 marks

Question 7

In an investigation of the corrosion of iron, students placed nails in tubes I, II and III containing dilute sodium chloride solution.



Tube I Tube II Tube III

Observations were:

Tube I	Nail	Some corrosion of the nail
Tube II	Nail in contact with zinc	Virtually no corrosion of the nail
Tube III	Nail in contact with tin	Great deal of corrosion of the nail

a. The initial step in the corrosion of iron involves the formation of iron(II) hydroxide from iron, water and oxygen.

Write half-equations for:

i. The oxidation process during corrosion.

ii. The reduction process during corrosion.

2 marks

b. i. Explain why the corrosion is least for the nail in contact with the zinc.

ii. Explain why the corrosion is greatest for the nail in contact with the tin.

2 marks

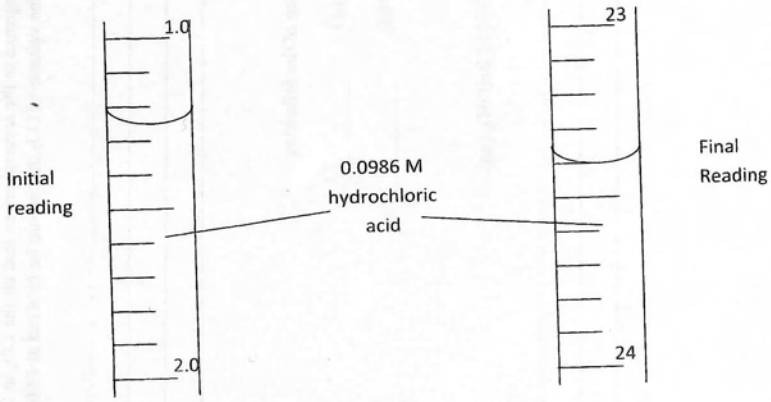
Total 4 marks

Question 8

The unknown concentration of a solution of sodium hydroxide can be determined by using hydrochloric acid solution of known concentration. The volumetric analysis can be carried out using phenolphthalein as an indicator. The results were as follows:

Concentration of hydrochloric acid = 0.0986 mol L^{-1}
Sample (aliquot) of sodium hydroxide taken = 20.00 mL

Magnified burette scale (mL) initially and finally is shown below.



a. Write a balanced equation for the reaction.

2 marks

b. Determine the volume of hydrochloric acid used.

2 marks

c. Calculate the amount, in mol, of hydrochloric acid used in the titration.

1 mark

d. Calculate the concentration of the sodium hydroxide solution in mol L^{-1}.

2 mark
Total 7 mark

END OF EXAMINATION

SECTION A (1 mark for each correct response)

1.	D	2.	C	3.	A	4.	C	5.	B
6.	D	7.	C	8.	D	9.	D	10.	A
11.	A	12.	C	13.	C	14.	A	15.	D
16.	A	17.	D	18.	B	19.	A	20.	D

Brief comments on Answers in Section A

Question 1
The number of atoms (and mass) are conserved in a chemical reaction. **Answer D**

Question 2
Group I cations e.g. Na^+, K^+ will not form precipitates. $BaSO_4$ is not soluble. **Answer C**

Question 3
None of the alternatives with a hydrocarbon can be soluble in water as hydrocarbon molecules are non-polar (not B, C or D). $CaCO_3$ is also insoluble in water. **Answer A**

Question 4

A. Correct mass but must be made up **to** 1 Litre of solution not 1 Litre added

B. Sodium chloride is not made up of molecules.

C. 5.85 g of sodium chloride per 1.00 L of solution **Correct**

D. Again, added to 1.00 L of distilled water is not correct – must be made up to 1 Litre.

Answer C

Question 5
$n(AlCl_3) = c \times V = 0.500 \times 0.100 = 0.0500$ mol $\quad n(Cl^-) = 3 \times n(AlCl_3) = 3 \times 0.0500 = 0.150$ mol

$n(NaCl) = c \times V = 0.500 \times 0.100 = 0.0500$ mol $\quad n(Cl^-) = n(NaCl) = 0.0500$ mol

$n(Cl^-)_{total} = 0.150 + 0.0500 = 0.200$ mol

$[Cl^-] = n/V = 0.200 / 0.200 = 1.00$ M **Answer B**

Question 6

$$H_2(g) + Cl_2(g) \rightarrow 2\,HCl(g)$$

n_i	3	2	
n_r	2	2	
n_p			4

Therefore 1 mol of H_2 remains and 4 mol of HCl are produced. **Answer D**

Question 7
Diluting by a factor of 100 makes the pH increase(less acidic) by a factor of 2. **Answer C**

Question 8
Indeed all four statements are correct about acids. **Answer D**

Question 9

$nMg(OH)_2 = m / M = 400 \times 10^{-3} / 58.3 = 6.86 \times 10^{-3}$ mol

$n(OH^-) = 2 \times nMg(OH)_2 = 2 \times 6.86 \times 10^{-3} = 1.37 \times 10^{-2}$ mol in 10 mL

$n(OH^-)$ in 1 Litre $= 1.37 \times 10^{-2} \times 1000 / 10 = 1.37$ mol **Answer D**

Question 10

$m(S) = 5600 \times 1/100 = 56$ tonnes

$n(S) = m/M = 56 \times 10^6 / 32.1 = 1.74 \times 10^6$ mol

$n(SO_2) = n(S) = 1.74 \times 10^6$ mol

$m(SO_2) = n(SO_2) \times M(SO_2) = 1.74 \times 10^6 \times 64.1 = 1.12 \times 10^8$ g $= 112$ tonnes **Answer A**

Question 11
Being a weak acid, only a small percentage of molecules are ionised at any point in time. **Answer A**

Question 12

$C = n/V \quad V = n/C = 0.100 / 0.125 = 0.800$ L $= 800$ mL **Answer C**

Question 13
If $PV = nRT$ and P and T are constants, V is directly proportional to n

$n(O_2) = m/M = 64/32 = 2$ mol occupies 50 ml

$n(O_3) = m/M = 144/48 = 3$ mol must occupy 75 mL **Answer C**

Question 14
As P and T are constant, V is directly proportional to n

$$3O_2(g) + 4NH_3(g) \rightarrow 2N_2(g) + 6H_2O(g)$$

V_i	60	20	
V_r	**15**	**20**	
V_p			**10**

Answer A

Question 15
Pressure is directly proportional to T in Kelvin.
To double the pressure, the temperature in Kelvin must be doubled.
Initial temperature is 290 K so need 580 K. **Answer D**

Question 16
The potassium atom loses an electron to form K^+. Potassium is therefore acting as a reductant.
Answer A

Question 17
Picking out all possible oxidant/reductant pairs in their correct order from the ES gives,

Fe^{3+} / Fe^{2+} + 0.77
Sn^{4+} / Sn^{2+} + 0.15
Sn^{2+} / Sn - 0.14
Ni^{2+} / **Ni** - 0.23
Fe^{2+} / Fe - 0.44
Zn^{2+} / Zn - 0.76

For reaction to occur, the oxidant must be placed higher than the reductant.

This only happens for the Sn^{2+} and Ni combination. **Answer D**

Question 18

Sn^{2+} / Sn - 0.14
Fe^{2+} / Fe - 0.44

An oxidation reaction is the loss of electrons. The Sn^{2+} is reduced (gains electrons) and the Fe is oxidised (loses electrons). **Answer B**

Question 19
The largest volume corresponds to the greatest number of mol at constant T and P

1.0 g CH_4 = 1/16 = 0.0625 mol

1.0 g O_2 = 1/32 = 0.0313 mol

1.0 g CO_2 = 1/44 = 0.0227 mol

CH_4 would have the largest volume. **Answer A**

Question 20
Soluble carbonates are (weak) bases. **Answer D**

SECTION B

Question 1 (7 marks)

a. $m(NO) = 1.00 \times 10^3$ g **1 mark**

$n(NO) = m/M = 1.00 \times 10^3 / 30.0 = 33.3$ mol **1 mark** (watch for consequential marks)

$n(NH_3) = n(NO)$ **1 mark** (there must be a clear statement of this for the mark)

$m(NH_3) = n \times M = 33.3 \times 17.0 = 566$ g **1 mark**

b. $n(H_2O) = m/M = 1.00 \times 10^3 / 18.0 = 55.6$ mol **1 mark**

$n(O_2) = 5/6\ n(H_2O)$ **1 mark**

$n(O_2) = 46.3$ mol **1 mark**

Question 2 (7 marks)

a. $3NaOH(aq) + FeCl_3(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$ (accept ionic version)
1 mark for correct formulae, 1 mark for balance

b. $3NaOH(aq) + FeCl_3(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$

$n_{initially}$ 9.0×10^{-3} 10×10^{-3} **2 marks**

$n_{required}$ 9.0×10^{-3} : 3.0×10^{-3}

$FeCl_3$ is in excess by 7.0×10^{-3} mol **1 mark**

c. $n(FeCl_3)_{reacting} = n(Fe(OH)_3)$ $M(Fe(OH)_3) = 106.8$ gmol^{-1} **1 mark**

$m(Fe(OH)_3) = 3.0 \times 10^{-3} \times 106.8 = 0.32$ g **1 mark**

Question 3 (8 marks)

a. $[H_2SO_4] = 0.0500$ M $\Rightarrow$ $[H^+] = 0.100$ M **1 mark**

$pH = -\log_{10}[H^+] = -\log_{10} 0.10 = 1.0$ **1 mark**

b. $n(H_2SO_4) = c \times V = 0.0500 \times 250 \times 10^{-3} = 1.25 \times 10^{-2}$ mol **1 mark**

$n(H^+) = 2 \times n(H_2SO_4) = 2.50 \times 10^{-2}$ mol **1 mark**

c. $[H^+] = n/V = 2.50 \times 10^{-2} / 1.0 = 0.0250$ M **1 mark**

$pH = -\log_{10}[H^+] = -\log_{10} 0.025 = 1.6$ **1 mark**

d. $n(OH^-) = n(H^+) = 2.50 \times 10^{-2}$ mol **1 mark**

$V = n/c = 2.50 \times 10^{-2} / 0.10 = 0.250$ L = 250 mL **1 mark**

Question 4 (4 marks)

P, V are constants, so in PV = nRT $\Rightarrow$ nT = constant **1 mark**

$\Rightarrow n_1T_1 = n_2T_2$
$\Rightarrow n_2/n_1 = T_1/T_2$
$\Rightarrow n_2/0.50 = 280/320$
$\Rightarrow n_2 = 0.50 \times 280/320 = 0.438$ mol **1 mark**
$\Rightarrow m(O_2) = 0.44 \times 32 = 14.0$ g **1 mark**
$\Rightarrow m(O_2)$ let out = 16.0 – 14.0 = 2.0 g **1 mark** Other methods are possible.

Question 5 (14 marks)

For each part, 1 mark for correct formulae, 1 mark for correct balance. States not required.

a. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

b. $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$ (It is also possible to form HCO_3^-)

c. $H_2SO_4 + Ba(OH)_2 \rightarrow BaSO_4 + 2H_2O$

d. $2HCl + MgCO_3 \rightarrow MgCl_2 + CO_2 + H_2O$

e. $N_2 + O_2 \rightarrow 2NO$

f. $2H_2O_2 \rightarrow O_2 + 2H_2O$

g. $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

Question 6 (10 marks)

a. **i.** $H_2CO_3(aq) + H_2O(l) \rightarrow H_3O^+(aq) + HCO_3^-(aq)$ **1 mark**
$HCO_3^-(aq) + H_2O(l) \rightarrow H_3O^+(aq) + CO_3^{2-}(aq)$ **1 mark**

ii. At any point in time, relatively few molecules are ionising. **1 mark**

b. PV = nRT $\Rightarrow$ V = nRT/P

n = m / M = 2.20 / 44.0 = 0.0500 mol **1 mark**

T = 313 K P = 101.3 kPa both correct **1 mark**

V = (0.0500 x 8.31 x 313) / 101.3 = 1.28 L **1 mark**

c. **i.** OH^- **1 mark** **ii.** NH_4^+ **1 mark**

d. 0.00500 M $Ba(OH)_2 \Rightarrow [OH^-] = 0.0100$M **1 mark**

$\Rightarrow [H^+] = 1.00 \times 10^{-12}$ M $\Rightarrow$ pH = 12 **1 mark** **or** pOH = 2 $\Rightarrow$ pH = 12

Question 7 (4 marks)

a. **i.** $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$ **1 mark**

ii. $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ **1 mark**

b. **i.** Zinc is more reactive (a stronger reductant) than iron and sacrificially provides electrons for the iron which cannot therefore be oxidised. **1 mark**

ii. Tin is less reactive (a weaker reductant) than zinc. Iron will oxidise to provide electrons for the tin. **1 mark**

Question 8 (7 marks)

a. $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ **1 mark for equation and 1 mark for states**

b. 23.40 (± 0.02) - 1.25 (± 0.02) = 22.15 (± 0.04) mL **1 mark for each reading = 2 marks**

c. $n(HCl) = c \times V = 0.0986 \times 22.15 \times 10^{-3} = 2.18 \times 10^{-3}$ mol **1 mark**

d. n(NaOH) = n(HCl) **1 mark**

$[NaOH] = n/V = 2.18 \times 10^{-3} / 20.0 \times 10^{-3} = 0.109$ M **1 mark**

END OF SUGGESTED SOLUTIONS