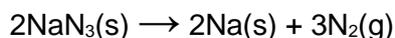
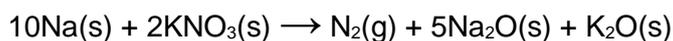


**Q23.**

In a car airbag, sodium azide ( $\text{NaN}_3$ ) decomposes to form sodium metal and nitrogen gas.



The sodium metal then reacts with potassium nitrate to produce more nitrogen gas.



If 2.00 mol of sodium azide react in this way, how many molecules of  $\text{N}_2$  will be formed?  
(The Avogadro constant  $L = 6.022 \times 10^{23} \text{ mol}^{-1}$ )

A  $2.41 \times 10^{24}$

B  $1.93 \times 10^{24}$

C  $1.81 \times 10^{24}$

D  $9.63 \times 10^{23}$

(Total 1 mark)

**Q24.**

Refrigerants are substances used to cool refrigerators and freezers. Until recently, many of the compounds used as refrigerants were chlorofluorocarbons (CFCs), but these are now known to form chlorine radicals. CFCs have been phased out in many countries by international agreement.

- (a) Write **two** equations to show how chlorine radicals react with ozone molecules in the upper atmosphere.

1. \_\_\_\_\_

2. \_\_\_\_\_

(2)

- (b) Chloropentafluoroethane is a CFC that has been used as a refrigerant.

Draw its displayed formula.

(1)



- (c) 1,1,1-trifluoroethane ( $\text{CF}_3\text{CH}_3$ ) is one of the molecules that has been used as a refrigerant in place of CFCs.

Explain why 1,1,1-trifluoroethane does not lead to the depletion of the ozone in the upper atmosphere.

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(1)

- (d) One of the steps in the synthesis of 1,1,1-trifluoroethane ( $\text{CF}_3\text{CH}_3$ ) is the reaction of 1,1-difluoroethane ( $\text{CHF}_2\text{CH}_3$ ) with fluorine in a free-radical substitution reaction.

Write **two** equations to represent the propagation steps in this conversion of  $\text{CHF}_2\text{CH}_3$  into  $\text{CF}_3\text{CH}_3$

Propagation step 1

---

Propagation step 2

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(2)

- (e) A refrigerator contains 1.41 kg of 1,1,1-trifluoroethane ( $\text{CF}_3\text{CH}_3$ ).

Calculate the number of molecules of 1,1,1-trifluoroethane in the refrigerator.  
Give your answer to an appropriate number of significant figures.  
(The Avogadro constant  $L = 6.022 \times 10^{23} \text{ mol}^{-1}$ )

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(2)

- (f) There are growing concerns about the use of 1,1,1-trifluoroethane as a refrigerant as it is a greenhouse gas that absorbs some of Earth's infrared radiation.

Give **one** reason why bonds in molecules such as carbon dioxide and 1,1,1-trifluoroethane absorb infrared radiation.

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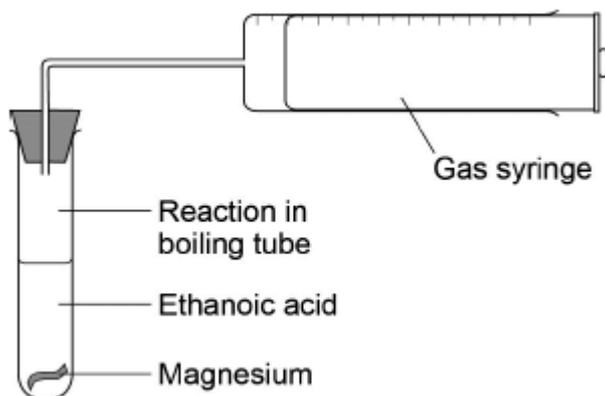
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(1)

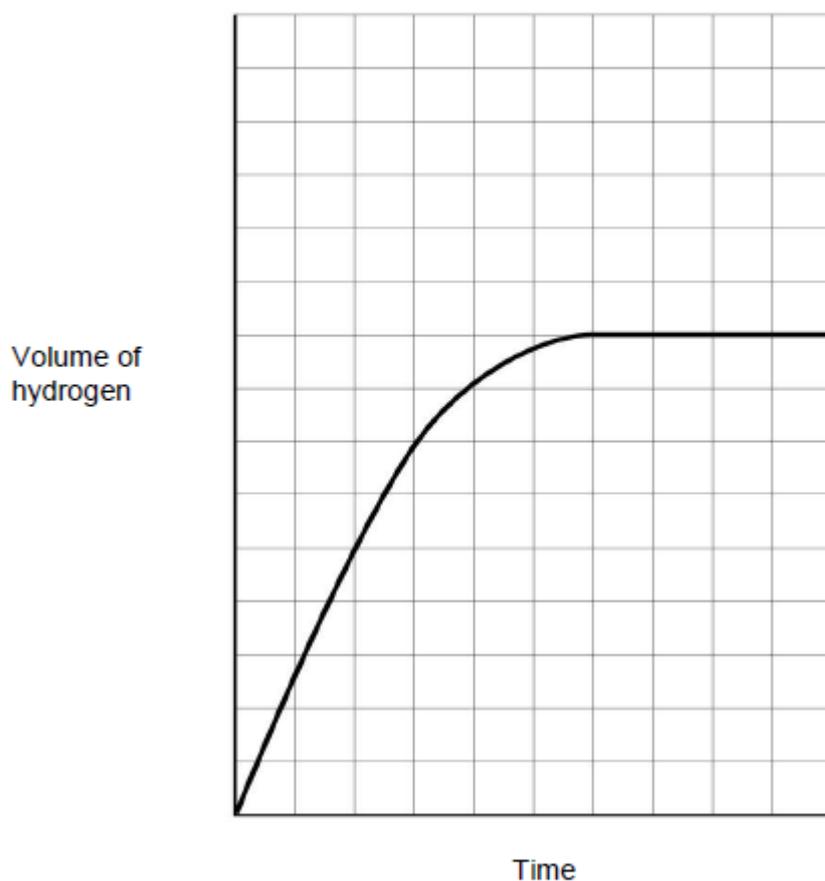
(Total 9 marks)

**Q25.**

When an aqueous solution of ethanoic acid reacts with magnesium, the progress of reaction can be followed using the equipment shown in **Figure 1** to measure the volume of hydrogen produced.

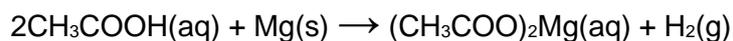
**Figure 1**

**Figure 2** shows how the volume of hydrogen produced varies with time when 396 mg of magnesium are added to 30.0 cm<sup>3</sup> of 0.600 mol dm<sup>-3</sup> ethanoic acid.

**Figure 2**



- (a) The equation for the reaction between ethanoic acid and magnesium is shown.



With the aid of calculations, show that the magnesium is in excess in this reaction.

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(3)

- (b) The reaction was repeated using 20 cm<sup>3</sup> of 0.800 mol dm<sup>-3</sup> of ethanoic acid solution with all other conditions the same. The magnesium was still in excess.

Sketch a line on **Figure 2** to show how the volume of hydrogen produced varies with time in this second experiment.

Space for working.

(2)

(Total 5 marks)

**Q26.**

The  $M_r$  of hydrated copper sulfate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) is 249.6.

Which of the following is the mass of hydrated copper sulfate required to make  $50.0 \text{ cm}^3$  of a  $0.400 \text{ mol dm}^{-3}$  solution?

- A 3.19 g
- B 3.55 g
- C 3.71 g
- D 4.99 g

(Total 1 mark)

**Q27.**

Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

- (a) People who have a zinc deficiency can take hydrated zinc sulfate ( $\text{ZnSO}_4 \cdot x\text{H}_2\text{O}$ ) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer  $x$  in  $\text{ZnSO}_4 \cdot x\text{H}_2\text{O}$

Show your working.

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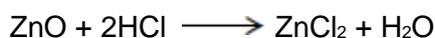
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(3)



- (b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.  
The equation for the reaction is



A 0.0830 mol sample of pure zinc oxide was added to 100 cm<sup>3</sup> of 1.20 mol dm<sup>-3</sup> hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

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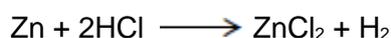
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(4)

- (c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.



An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.  
Give your answer to 3 significant figures.

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(4)



- (d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

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(3)

(Total 14 marks)

### Q28.

Norgessalpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula  $\text{Ca}(\text{NO}_3)_2$

- (a) Norgessalpeter can be made by the reaction of calcium carbonate with dilute nitric acid as shown by the following equation.



In an experiment, an excess of powdered calcium carbonate was added to  $36.2 \text{ cm}^3$  of  $0.586 \text{ mol dm}^{-3}$  nitric acid.

- (i) Calculate the amount, in moles, of  $\text{HNO}_3$  in  $36.2 \text{ cm}^3$  of  $0.586 \text{ mol dm}^{-3}$  nitric acid. Give your answer to 3 significant figures.

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(1)

- (ii) Calculate the amount, in moles, of  $\text{CaCO}_3$  that reacted with the nitric acid. Give your answer to 3 significant figures.

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(1)

- (iii) Calculate the minimum mass of powdered  $\text{CaCO}_3$  that should be added to react with all of the nitric acid.

Give your answer to 3 significant figures.

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(2)



- (iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

\_\_\_\_\_

(1)

- (b) Norgessalt peter decomposes on heating as shown by the following equation.



A sample of Norgessalt peter was decomposed completely.

The gases produced occupied a volume of  $3.50 \times 10^{-3} \text{ m}^3$  at a pressure of 100 kPa and a temperature of 31 °C.

(The gas constant  $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$ )

- (i) Calculate the total amount, in moles, of gases produced.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(3)

- (ii) Hence calculate the amount, in moles, of oxygen produced.

\_\_\_\_\_  
\_\_\_\_\_

(1)

- (c) Hydrated calcium nitrate can be represented by the formula  $\text{Ca}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$  where  $x$  is an integer.

A 6.04 g sample of  $\text{Ca}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$  contains 1.84 g of water of crystallisation.

Use this information to calculate a value for  $x$ .

Show your working.

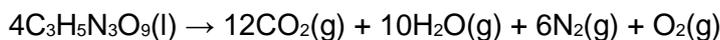
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(3)

(Total 12 marks)

**Q29.**

Nitroglycerine,  $C_3H_5N_3O_9$ , is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.



(a) A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas.

(i) State what is meant by the term *one mole* of molecules.

\_\_\_\_\_

(ii) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

*Moles of oxygen gas* \_\_\_\_\_

*Total moles of gas* \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(iii) Calculate the number of moles, and the mass, of nitroglycerine detonated.

*Moles of nitroglycerine* \_\_\_\_\_

\_\_\_\_\_

*Mass of nitroglycerine* \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(7)

(b) A second sample of nitroglycerine was placed in a strong sealed container and detonated. The volume of this container was  $1.00 \times 10^{-3} \text{ m}^3$ . The resulting decomposition produced a total of 0.873 mol of gaseous products at a temperature of 1100 K.

State the ideal gas equation and use it to calculate the pressure in the container after detonation.

(The gas constant  $R = 8.31 \text{ J K}^{-1}\text{mol}^{-1}$ )

*Ideal gas equation* \_\_\_\_\_

*Pressure* \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

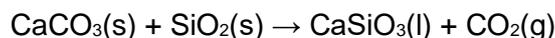
\_\_\_\_\_

(4)

(Total 11 marks)

**Q30.**

The removal of silicon dioxide with limestone in the Blast Furnace can be represented by the following equation.



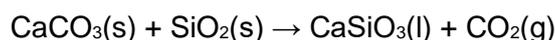
The minimum mass of calcium carbonate needed to remove 1.00 tonne (1000 kg) of silicon dioxide is

- A 0.46 tonne
- B 0.60 tonne
- C 1.67 tonne
- D 2.18 tonne

(Total 1 mark)

**Q31.**

The removal of silicon dioxide with limestone in the Blast Furnace can be represented by the following equation.



The volume of carbon dioxide, measured at 298 K and  $1.01 \times 10^5$  Pa, formed in this reaction during the removal of 1.00 tonne (1000 kg) of silicon dioxide is

- A 24.5 dm<sup>3</sup>
- B 408 dm<sup>3</sup>
- C 24.5 m<sup>3</sup>
- D 408 m<sup>3</sup>

(Total 1 mark)

**Q32.**

(a) Complete the following table.

	Relative mass	Relative charge
Neutron		
Electron		

(2)

(b) An atom has twice as many protons as, and four more neutrons than, an atom of <sup>9</sup>Be. Deduce the symbol, including the mass number, of this atom.

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(2)



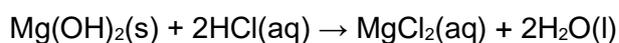
- (c) Draw the shape of a molecule of  $\text{BeCl}_2$  and the shape of a molecule of  $\text{Cl}_2\text{O}$ . Show any lone pairs of electrons on the central atom. Name the shape of each molecule.



Name of shape \_\_\_\_\_ Name of shape \_\_\_\_\_

(4)

- (d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.



Calculate the volume, in  $\text{cm}^3$ , of  $1.00 \text{ mol dm}^{-3}$  hydrochloric acid required to react completely with  $1.00 \text{ g}$  of magnesium hydroxide.

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(4)

(Total 12 marks)



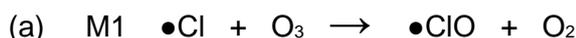
## Mark Scheme

**Q23.**

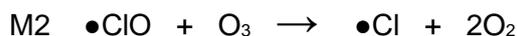
B

[1]

**Q24.**



1



1

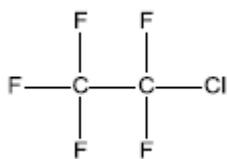
*M1 and M2 could be in either order*

*Credit the dot anywhere on the radical*

*Penalise absence of dot once only*

*Individual multiples acceptable but both need to be doubled if two marks are to be awarded*

*Ignore state symbols*



*Must be displayed formula*

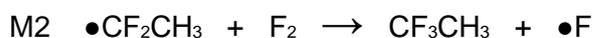
1

- (c) Does not contain Cl or does not release Cl (atoms/radicals)  
or no C-Cl bonds  
or C-F bond(s) strong / does not break / no F (atom/radicals) released

1



1



1

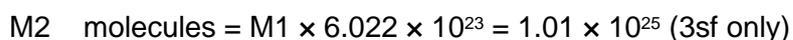
*M1 and M2 could be in either order*

*Credit the dot anywhere on the radical*

*Penalise absence of dot once only*



1



1

*Correct answer scores both marks*

*Allow M2 for  $\text{M1} \times \text{Avogadro}$  with answer to 3 sf (but must have attempted to calculate moles for M1)*

*Ignore incorrect units*



- (f) (bonds) vibrate/stretch/bend OR (as bonds) are polar  
*NOT polar molecules; 'they' = bonds*

1

[9]

**Q25.**(a) **Method 1**

*Allow working throughout to 2sf*

M1 Moles of Mg =  $0.396/24.3 = 0.0163$

1

M2 Moles of CH<sub>3</sub>COOH =  $0.600 \times 30.0/1000 = 0.018$

1

- M3 Mark for showing Mg is in excess: either  
 0.018 mol of CH<sub>3</sub>COOH reacts with 0.009 mol of Mg OR  
 0.0163 mol of Mg reacts with 0.0326 mol of CH<sub>3</sub>COOH OR  
 0.0073 mol of Mg is in excess

1

*If candidate gets 16.3 mol (as not converted mg to g) in method 1 or 3 then can only score 1 mark maximum (M2)*

*Accept other valid calculations that show the Mg is in excess*

**Method 2**

M1 Moles of CH<sub>3</sub>COOH =  $0.600 \times 30.0/1000 = 0.018$

M2 Moles of Mg that would react with this = 0.009

- M3 Mass of Mg needed =  $24.3 \times 0.009 = 0.219$  g which is less than 0.396 g OR  
 Moles of Mg = 0.0163 which is more than 0.009 required

**Method 3**

M1 Moles of Mg =  $0.396/24.3 = 0.0163$

M2 Moles of CH<sub>3</sub>COOH that would react with this = 0.0326

- M3 Volume of CH<sub>3</sub>COOH needed =  $0.0326 / 0.60 = 0.0543$  dm<sup>3</sup>  
 (54.3 cm<sup>3</sup>) which is more than 0.030 dm<sup>3</sup> (30 cm<sup>3</sup>)

- (b) M1 Line starts at origin and is steeper

1

- M2 (moles CH<sub>3</sub>COOH =  $0.800 \times 20/1000 = 0.016$ ) line levels out on 8<sup>th</sup> line up (line below the original 9<sup>th</sup> line)

*M2 for line on 8<sup>th</sup> line on grid (original on 9<sup>th</sup> line) – allow some leniency so long as clear it ends at (or very close to) the 8<sup>th</sup> line; and line does not significantly wobble*

1

[5]

**Q26.**

D

[1]



## Q27.

(a)

Method 1

Mass of H<sub>2</sub>O = 4.38–2.46  
(= 1.92 g)

Method 2

Percentage of H<sub>2</sub>O = 44%

*If there is an AE in M1 then can score M2 and M3*

*If M<sub>r</sub> incorrect can only score M1*

ZnSO<sub>4</sub>H<sub>2</sub>OZnSO<sub>4</sub>H<sub>2</sub>O2.461.925644

161.5

18

161.5

18

1

(0.0152

0.107)

(0.347

2.444)

( 1 : 7 )

( 1 : 7 )

x = 7

x = 7

*If x = 7 with working then award 3 marks.*

*Allow alternative methods.*

*If M1 incorrect due to AE, M3 must be an integer.*

1

1

(b) Moles HCl = 0.12(0)

1

mol ZnCl<sub>2</sub> = 0.06(0) **OR** 0.12 / 2

1

*If M2 incorrect then CE and cannot score M2, M3 and M4.*

mass ZnCl<sub>2</sub> = 0.06 × 136.4

*Allow 65.4 + (2 × 35.5) for 136.4*

1

= 8.18(4) (g) **OR** 8.2 (g)

*Must be to 2 significant figures or more.*

*Ignore units.*

1

(c) Moles ZnCl<sub>2</sub> =  $\frac{10.7}{136.4}$  (= 0.0784)

1

**OR** moles Zn = 0.0784

Mass Zn reacting = 0.0784 × 65.4 = (5.13 g)

*M2 is for their M1 × 65.4*

1



$$\% \text{ purity of Zn} = \frac{5.13}{5.68} \times 100$$

M3 is  $M2 \times 100 / 5.68$  provided M2 is  $< 5.68$

1

= 90.2% **OR** 90.3%

*Allow alternative methods.*

$$M1 = \text{Moles ZnCl}_2 = \frac{10.7}{136.4} (= 0.0784)$$

$$M2 = \text{Theoretical moles Zn} = \frac{5.68}{65.4} (= 0.0869)$$

$$M3 = M1 \times 100 / M2 = (0.0784 \times 100 / 0.0869)$$

$$M4 = \underline{90.2\%} \text{ OR } \underline{90.3\%}$$

1

(d) Ionic

*If not ionic CE = 0/3*

1

Strong (electrostatic) attraction (between ions)

1

between oppositely charged ions / + and - ions /  $F^-$  and  $Zn^{2+}$  ions

*If IMF, molecules, metallic bonding implied CE = 0/3*

1

[14]

### Q28.

(a) (i) 0.0212

*Need 3 sig figs*

*Allow correct answer to 3 sig figs eg  $2.12 \times 10^{-2}$*

1

(ii) 0.0106

*Mark is for (a)(i) divided by 2 leading to correct answer 2 sig figs*

1

(iii)  $M_r = \underline{100.1}$

1.06 g

*Allow 100.1 as 'string'*

*Need 3 sig figs or more*

*Consequential on (a)(ii)  $\times 100(.1)$*

2

(iv) Neutralisation or acid / base reaction

*Allow acid / alkali reaction*

*Apply list principle*

1



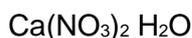
- (b) (i)  $T = 304(\text{K})$  and  $P = 100\,000$  (Pa)  
*Only T and P correctly converted* 1

$$\frac{100\,000 \times 3.50 \times 10^{-3}}{8.31 \times 304} \text{ OR } n = \frac{PV}{RT} \quad \text{1}$$

0.139 (mol)  
*Allow 0.138 – 0.139* 1

- (ii) 0.0276 – 0.0278(mol)  
*Allow answer to (b)(i) divided by 5 leading to a correct answer*  
*Allow 0.028* 1

- (c) 4.20 g  $\text{Ca}(\text{NO}_3)_2$  1



$$\frac{4.20}{164(.1)} \quad \frac{1.84}{18}$$

*Mark is for dividing by the correct Mr values*  
*M2 and M3 dependent on correct M1*

0.0256      0.102  
*M2 can be awarded here instead*

1      :      3.98

$x = 4$

*If  $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$  seen with working then award 3 marks*  
*Credit alternative method which gives  $x = 4$*  1

[12]

### Q29.

- (a) (i) Avogadro's number/constant of molecules/particles/species /  $6 \times 10^{23}$   
*[Not 'atoms']* 1

**Or** same number of particles as (there are atoms)  
*[Not molecules]*

in 12.(00)g of  $^{12}\text{C}$  1

- (ii) Moles  $\text{O}_2 = \frac{0.350}{32}$  ( $= 1.09 \times 10^{-2}$  mol) 1



$$= 29 (\times 1.09 \times 10^{-2})$$

*[Accept answers via 4 separate mole calculations]*

1

$$= 0.316 - 0.317 \text{ mol [answer to 3 + sf]}$$

*[Mark conseq on errors in M1/M2] (1)*

1

(iii) Moles of nitroglycerine =  $4 \times 1.09 \times 10^{-2}$  (= 0.0438 mol)

*[Mark conseq on their moles of O<sub>2</sub>]*

1

$$M_r \text{ of nitroglycerine} = 227 \text{ or number string}$$

1

$$\text{Moles of nitroglycerine} = 227 \times 0.0438 = 9.90 - 9.93(\text{g})$$

*[answer to 3+ sf]*

*[If string OK but final answer wrong then allow M6 but AE for M7]*

*[Mark conseq on error in M<sub>r</sub>] [Penalise wrong units]*

*[Penalise sig. fig. errors once only in whole question]*

(b)  $pV = nRT$  or  $pV = \frac{nRT}{V}$  or  $p = \frac{nRT}{V}$

1

$$p = \frac{nRT}{V} = \frac{0.873 \times 8.31 \times 1100}{1.00 \times 10^{-3}}$$

1

$$= 7980093 \text{ or } 7980 \text{ or } 7.98$$

*[ignore s.f.]*

1

$$\text{units} = \text{Pa or kPa or MPa} \quad (\text{as appropriate})$$

*[If error in conversion from Pa, treat as a contradiction of the units mark]*

*[If transfer error, mark conseq but penalise M2]*

*[If data from outside of above used, penalise M2 and M3]*

*[If pV expression incorrectly rearranged, penalise M2 and M3]*

*[if T = 1373 K used, penalise M2]*

1

[11]

Q30.

C

[1]

Q31.

D

[1]

**Q32.**

(penalty for sig fig error = 1 mark per question)

- (a) neutron: relative mass = 1 relative charge = 0  
(not 'neutral')

1

electron: relative mass =  $1/1800 \rightarrow 0$ /negligible or

$5.56 \times 10^{-4} \rightarrow 0$  relative charge = -1

1

- (b)  $^{17}\text{O}/\text{O}^{17}$  mass number (Do not accept 17.0)

1

oxygen symbol 'O'

(if 'oxygen' + — 'mass number = 17'(1))

(if 'oxygen'+ — 'mass number = 17'(0))

(if at  $N^0$  given but  $\neq 8$ , treat as 'con' for M2)

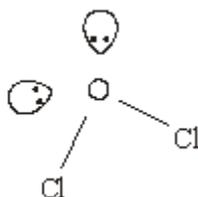
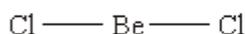
(if lp on Be, diagram = 0)

(ignore bond angles)

(not dot and cross diagrams)

1

- (c)



2

QoL Linear (1)

bent / V-shaped / angular (1)

(mark name and shape independently)

(accept (distorted) tetrahedral)

(if balls instead of symbols, lose M1 – can award M2)

(penalise missing 'Cl' once only)

(not 'non-linear')

2

- (d)  $M_r(\text{Mg}(\text{NO}_3)_2) = 58(.3)$  (if At  $N^0$  used, lose M1 and M2)

1

moles  $\text{Mg}(\text{OH})_2 = 0.0172$  (conseq on wrong M2) (answer to 3+ s.f.)

1

moles  $\text{HCl} = 2 \times 0.0172 = 0.0344$  or  $0.0343$  (mol) (process mark)

1

$$\text{vol HCl} = \frac{0.0343 \times 1000}{1} = 34.3 - 34.5 \text{ (cm}^3\text{)} \text{ (unless wrong unit)}$$

(if candidate **used** 0.017 or 0.0171 lose M2)



*(just answer with no working, if in range = (4).*

*if, say, 34 then =(2))*

*(if not 2:1 ratio, lose M3 and M4)*

*(if work on HCl, CE = 0/4)*

**1**

**[12]**