

4.2 The mole concept

01. 0620_w21_qp_43 Q: 4

Carbon is an important element.

(a) Carbon exists as the isotopes $^{12}_6\text{C}$ and $^{13}_6\text{C}$.

Complete the table.

isotope	number of protons in one atom	number of electrons in one atom	number of neutrons in one atom
$^{12}_6\text{C}$			
$^{13}_6\text{C}$			

[2]

(b) Name **two** forms of the element carbon which have giant covalent structures.

..... and [1]

(c) The Avogadro constant is the number of particles in 1 mole.

The numerical value of the Avogadro constant is 6.02×10^{23} .

(i) Calculate the number of molecules in 22.0g of carbon dioxide, CO_2 .

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..... molecules [2]

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(ii) Calculate the number of molecules in 6.00 dm^3 of carbon dioxide gas at room temperature and pressure.

..... molecules [1]

[Total: 6]

02. 0620_s20_qp_41 Q: 1

This question is about elements **X**, **Y** and **Z**.

(a) An atom of element **X** is represented as ${}_{16}^{34}\text{X}$.

(i) Name the different types of particles found in the nucleus of this atom of **X**.

.....
 [2]

(ii) What is the term for the total number of particles in the nucleus of an atom?

..... [1]

(iii) What is the total number of particles in the nucleus of an atom of ${}_{16}^{34}\text{X}$?

..... [1]

(iv) What is the electronic structure of the ion X^{2-} ?

..... [1]

(v) Suggest the formula of the compound formed between aluminium and **X**.

..... [1]

(b) (i) What term is used to describe atoms of the same element with different numbers of particles in the nucleus?

..... [1]

(ii) Identify the atom against which the relative masses of all other atoms are compared.

..... [1]

(iii) What is the name of the amount of any substance that contains 6.02×10^{23} particles?

..... [1]

(iv) The constant 6.02×10^{23} has a name.

What is the name of this constant?

..... [1]

4.2. THE MOLE CONCEPT

(c) Part of the definition of relative atomic mass is 'the average mass of naturally occurring atoms of an element'.

Some relative atomic masses are not whole numbers.

Element Y has only two different types of atom, ^{69}Y and ^{71}Y .

The ratio of atoms present in element Y is shown.

$$^{69}\text{Y} : ^{71}\text{Y} = 3 : 2$$

- Calculate the relative atomic mass of element Y to **one decimal place**.

relative atomic mass =

- Identify element Y.

..... [3]

(d) Element Z is in Period 3 and Group V.

- (i) Identify element Z.

..... [1]

- (ii) Explain in terms of electron transfer why Z behaves chemically as a non-metal.

..... [2]

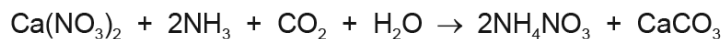
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[Total: 16]

03. 0620_w19_qp_43 Q: 5

Nitrates such as ammonium nitrate are used as fertilisers.

The final stage in the production of ammonium nitrate is shown in the equation.



Calculate the maximum mass of ammonium nitrate that can be produced from 820g of calcium nitrate, $\text{Ca}(\text{NO}_3)_2$, using the following steps.

The relative formula mass, M_r , of calcium nitrate, $\text{Ca}(\text{NO}_3)_2$, = 164.

- Calculate the number of moles of $\text{Ca}(\text{NO}_3)_2$ in 820g.

..... mol

- Deduce the number of moles of NH_4NO_3 produced.

..... mol

- Calculate the M_r of NH_4NO_3 .

M_r of NH_4NO_3 =

- Calculate the maximum mass of ammonium nitrate produced.

..... g
[4]

4.2. THE MOLE CONCEPT

04. 0620_s18_qp_41 Q: 4

This question is about masses, volumes and moles.

(a) Which term is defined by the following statement?

The average mass of naturally occurring atoms of an element on a scale where the ^{12}C atom has a mass of exactly 12 units.

..... [1]

(b) Butane, C_4H_{10} , has a relative **molecular** mass of 58.
Potassium fluoride, KF, has a relative **formula** mass of 58.

Explain why the term relative molecular mass can be used for butane but **cannot** be used for potassium fluoride.

.....
..... [2]

(c) A 0.095 g sample of gaseous element Y occupies 60.0 cm^3 at room temperature and pressure.

- Determine the number of moles of element Y in 60.0 cm^3 .

moles of element Y = mol

- Calculate the relative molecular mass of element Y and hence suggest the identity of element Y.

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relative molecular mass =

identity of element Y =

[3]

- (d) A 1.68 g sample of phosphorus was burned and formed 3.87 g of an oxide of phosphorus.

Calculate the empirical formula of this oxide of phosphorus.

empirical formula = [4]

- (e) Another oxide of phosphorus has the empirical formula P_2O_3 .
One molecule of this oxide of phosphorus contains four atoms of phosphorus.

Calculate the mass of **one** mole of this oxide of phosphorus.

mass = g [2]

[Total: 12]

4.2. THE MOLE CONCEPT

05. 0620_m17_qp_42 Q: 6

Barium carbonate decomposes when heated.



(a) A student heated a 10.0g sample of barium carbonate until it was fully decomposed.

(i) Calculate the number of moles of barium carbonate the student used.

moles of barium carbonate = mol [2]

(ii) Calculate the volume of carbon dioxide gas produced at room temperature and pressure. Give your answer in dm^3 .

volume of carbon dioxide = dm^3 [1]

(b) The student added 2.00g of the barium oxide produced to water.

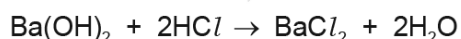


Calculate the mass of barium hydroxide that can be made from 2.00g of barium oxide. The M_r of $\text{Ba}(\text{OH})_2$ is 171.

mass of barium hydroxide = g [1]

(c) A 1.50g sample of barium hydroxide was dissolved in water. The total volume of the solution was 100cm^3 .

A 25.0cm^3 portion of the barium hydroxide solution was titrated against hydrochloric acid. The volume of hydrochloric acid required was 18.75cm^3 .



(i) Calculate how many moles of barium hydroxide were in the 25.0cm^3 portion used in the titration.

moles of barium hydroxide = mol [1]

(ii) Calculate the concentration of the hydrochloric acid used.

concentration of hydrochloric acid = mol/dm^3 [2]

[Total: 7]

06. 0620_w16_qp_41 Q: 7

Calcium chloride can be made by reacting calcium carbonate with hydrochloric acid.



An excess of calcium carbonate was added to 50.0 cm³ of 0.500 mol/dm³ hydrochloric acid. The solution was filtered to remove the excess calcium carbonate.

(a) How many moles of HCl were used in this reaction?

..... mol [2]

(b) Deduce the number of moles of carbon dioxide gas made in this reaction.

..... mol [1]

(c) Calculate the mass of carbon dioxide made in this reaction.

..... g [2]

(d) Calculate the volume, in dm³, of carbon dioxide made in this reaction at room temperature and pressure (r.t.p.).

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..... dm³ [1]

[Total: 6]

4.2. THE MOLE CONCEPT

07. 0620_s13_qp_32 Q: 8

(a) Define the following

(i) the mole

.....
..... [1]

(ii) the Avogadro constant

.....
..... [1]

(b) Which **two** of the following contain the same number of molecules?
Show how you arrived at your answer.

2.0 g of methane, CH₄

8.0 g of oxygen, O₂

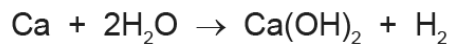
2.0 g of ozone, O₃

8.0 g of sulfur dioxide, SO₂

.....
.....
..... [2]

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(c) 4.8 g of calcium is added to 3.6 g of water. The following reaction occurs.



(i) the number of moles of Ca =

the number of moles of H₂O = [1]

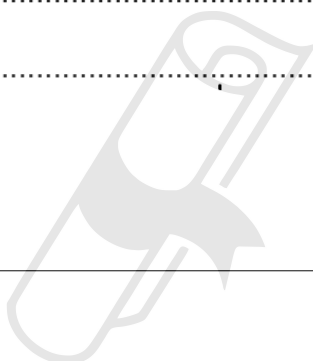
(ii) Which reagent is in excess? Explain your choice.

.....
 [2]

(iii) Calculate the mass of the reagent named in (ii) which remained at the end of the experiment.

.....
 [1]

[Total: 8]



01. 0620_w21_ms_43 Q: 4

Question	Answer	Marks						
(a)	1 mark for each row <table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td>6</td> <td>6</td> <td>6</td> </tr> <tr> <td>6</td> <td>6</td> <td>7</td> </tr> </table>	6	6	6	6	6	7	2
6	6	6						
6	6	7						
(b)	diamond and graphite	1						
(c)(i)	M1 (22 ÷ 44 =) 0.5 (moles) (1) M2 $3.01 \times 10^{23}(1)$	2						
(c)(ii)	1.505×10^{23}	1						

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(a)(i)	protons	1
	neutrons	1
(a)(ii)	nucleon number	1
(a)(iii)	34	1
(a)(iv)	2 : 8 : 8	1
(a)(v)	A_2X_3	1
(b)(i)	isotopes	1
(b)(ii)	^{12}C	1
(b)(iii)	a mole	1
(b)(iv)	Avogadro constant	1
(c)	M1 $(3 \times 69) + (2 \times 71)$ M2 $= \frac{349}{5} = 69.8$ M3 Y = Ga / gallium	3
(d)(i)	phosphorus / P	1
(d)(ii)	gains electrons three electrons (when forming ion)	2

03. 0620_w19_ms_43 Q: 5

	M1 5 moles of calcium nitrate (1) M2 10 moles ammonium nitrate (1) or ecf M1 \square 2 M 3 M_r of ammonium nitrate = 80 M4 800 g or ecf M2 \square M3	4
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04. 0620_s18_ms_41 Q: 4

(a)	relative atomic mass	1
(b)	C_4H_{10} is covalent	1
	KF is ionic	1
(c)	mol of Y = $0.060 / 24.0 = 2.5 \square 10^{-3}$ or 0.0025	1
	$M_r = 0.095 / 2.5 \square 10^{-3} = 38(.0)$	1
	fluorine	1
(d)	mass of O = $3.87 \text{ g} - 1.68 \text{ g} = 2.19 \text{ (g)}$	1
	mol of P and mol of O $1.68 / 31$ OR $0.054..$ $2.19 / 16$ OR $0.13...$	1
	ratio of P to O P = $0.054... / 0.054$ O = $0.13... / 0.054...$ = 1 = 2.5	1
	whole number ratio and P_2O_5 = 2 = 5	1
(e)	the formula is P_4O_6 or (one mole of) $P_2O_3 = 110 \text{ (g)}$	1
	mass = 220 (g)	1

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(a)(i)	M1 (relative formula mass $\text{BaCO}_3 =$) 197	1
	M2 ($10.0/197 =$) 0.0508 (0.0508 alone scores [2])	1
(a)(ii)	1.22	1
(b)	2.24	1
(c)(i)	0.00219	1
(c)(ii)	M1 moles $\text{HCl} = 2 \times 0.00219$ OR correct evaluation of this (= 0.00438)	1
	M2 ($0.00438/0.01875$) = 0.234 (0.234 alone scores [2])	1

06. 0620_w16_ms_41 Q: 7

(a)	0.025	1 1
	M1 $50/1000 (=0.05)$ M2 (0.05×0.5) = 0.025	
(b)	0.0125	1
(c)	0.55	1 1
	M1 44 M2 0.55	
(d)	0.3	1

07.0620_s13_ms_32 Q: 8

- (a) (i) (the number of particles which is equal to the number of atoms in) 12g of carbon 12
 or
 the mass in grams which contains the Avogadro's constant number of particles
 or
 Avogadro's constant **or** 6.023×10^{23} of atoms / ions / molecules / electrons / particles
 or
 (the amount of substance which has a mass equal to) its relative formula mass / relative atomic mass / relative molecular mass in grams
 or
 (the amount of substance which has a volume equal to) 24 dm³ of a gas at RTP [1]
- (ii) (Avogadro's constant is the) number of particles / atoms / ions / molecules in one mole of a substance
 or
 the number of carbon atoms in 12g of C(12).
 or
 the number of particles / molecules in 24 dm³ of a gas at RTP
 or
 6.023×10^{23} (particles / atoms / ions / molecules / electrons) [1]
- (b) CH₄ and SO₂ [1]
 $2/16 = 1/8$ or 0.125 moles of CH₄ **AND** $8/64 = 1/8$ or 0.125 moles of SO₂ [1]
- (c) (i) $4.8/40 = 0.12$ moles of Ca
 $3.6/18 = 0.2$ moles of H₂O **both** correct [1]
- (ii) Ca is in excess (**no mark**) (because 0.12 moles of Ca need) 0.24 moles / 4.32g of H₂O to react [1]
 there is not enough / there are 0.2 moles / 3.6g of H₂O [1]
 or
 Ca is in excess (**no mark**) (because 0.2 moles / 3.6g of water will react with) 0.1 moles / 4.0g of Ca [1]
 there is more than that / there are 0.12 moles / 4.8g of Ca [1]
 or
 Ca is in excess (**no mark**) because the mole ratio Ca:H₂O is 3:5 / mass ratio 4:3 [1]
 which is bigger than the required mole ratio of 1:2 / mass ratio 10:9 [1]
 or
 Ca is in excess (**no mark**) because the mole ratio H₂O:Ca is 5:3 / mass ratio 3:4 [1]
 which is smaller than the required mole ratio of 2:1 / mass ratio 9:10 [1]
- (iii) $0.02 \times 40 = 0.8$ (g) [1]