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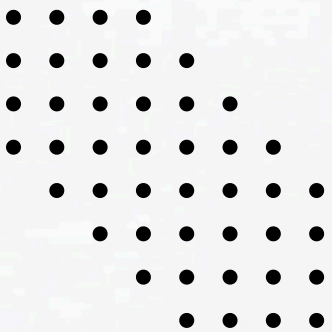
ATOMS, MOLECULES AND STOICHIOMETRY

Topical Questions



Compiled by :

Chembase School of Chemistry

1 Ethanedioic acid, HO_2CCO_2H, has a relative molecular mass of 90.0.

(a) (i) Explain what is meant by the term *relative molecular mass*.

.....

.....

..... [2]

(ii) State the empirical formula of ethanedioic acid.

..... [1]

(iii) Calculate how many atoms of carbon are present in 0.18 g of ethanedioic acid, HO_2CCO_2H.

Show your working.

atoms of carbon present = ... [3]

(b) Solid ethanedioic acid reacts with aqueous calcium ions to make a precipitate of calcium ethanedioate, CaC_2O_4.

CaC_2O_4 breaks down when heated to form calcium oxide, carbon dioxide and carbon monoxide.

(i) Construct an equation to represent the reaction of CaC_2O_4 when heated. Include state symbols.

..... [2]

(ii) Identify the type of reaction which occurs when CaC_2O_4 is heated.

..... [1]

(iii) Identify another compound containing calcium ions which will also produce carbon dioxide and calcium oxide when it is heated.

..... [1]

[Total: 10]

2 **(d)** The compound As_2S_3 is a common mineral.

When As_2S_3 is heated strongly in air, it forms a mixture of products, as shown.

$$2As_2S_3(s) + 9O_2(g) \rightarrow As_4O_6(s) + 6SO_2(g)$$

(i) A sample containing 0.198 g As_2S_3 is placed in 0.100 dm^3 of pure oxygen, an excess, in a reaction chamber connected to a gas syringe at room temperature.

The reactants are heated until no further change is observed. The products are then allowed to cool to room temperature.

Calculate the volume, in dm^3, of gas present at the end of the experiment.

The molar volume of gas is 24.0 $dm^3 mol^{-1}$ under these conditions. Assume that the pressure is constant throughout the experiment.

Show your working.

volume of gas remaining = ... dm^3
[4]

(ii) State the environmental consequences of releasing $SO_2(g)$ into the atmosphere.

..... [1]

(iii) $SO_2(g)$ can be removed from the air by reacting it with NaOH(aq).

Construct an equation for the reaction of $SO_2(g)$ with NaOH(aq). Include state symbols.

..... [2]

[Total: 21]

(e) A sample of magnesium contains three isotopes, ^{25}Mg, ^{26}Mg and **X**.

The percentage abundance of the three isotopes is shown in Table 1.1.

Table 1.1

isotope of Mg	mass/a.m.u.	percentage abundance/%
X		78.99
^{25}Mg	24.99	10.00
^{26}Mg	25.98	11.01

(i) The relative atomic mass, A_r, is calculated by comparing the average mass of the isotopes of an element to the unified atomic mass unit.

Define the unified atomic mass unit.

..... [1]

(ii) Calculate the mass of **X**. Use data from Table 1.1 and A_r (magnesium) = 24.31 in your calculation. Show your working.

mass of **X** = ...
[2]

(iii) State **one** similarity and **one** difference in the properties of these isotopes of magnesium. Explain your answer.

.....

.....

..... [2]

3 Compound **V** is a liquid.

V contains 77.2% carbon, 11.4% hydrogen and 11.4% oxygen by mass.

V has a relative molecular mass of 280.

(a) Calculate the molecular formula of **V**. Show your working.

molecular formula of **V** = ... [3]

(b) **V** contains two types of functional group: a carboxylic acid and an alkene.

(i) Describe a chemical test and observation which confirms the presence of a carboxyl functional group.

.....

..... [2]

(ii) A 3.196 g sample of Br_2 reacts completely with 2.800 g of **V**.

Calculate how many alkene functional groups are present in one molecule of **V**. Show your working.

number of alkene functional groups in **V** = ... [1]

4 Atoms with nuclei containing an odd number of protons tend to have fewer isotopes than those with an even number of protons.

(a) Gallium has two stable isotopes, ^{69}Ga and ^{71}Ga.

(i) Complete Table 1.1 to show the numbers of protons, neutrons and electrons in the two stable isotopes of gallium.

Table 1.1

isotope	number of protons	number of neutrons	number of electrons
^{69}Ga			
^{71}Ga			

[2]

(ii) Define relative atomic mass.

.....

.....

..... [2]

(iii) The relative atomic mass of gallium, A_r, is 69.723.
The relative isotopic masses of ^{69}Ga and ^{71}Ga are:

^{69}Ga, 68.926; ^{71}Ga, 70.925.

Use this information to calculate the percentage abundance of ^{69}Ga in elemental gallium.
Show your working.
Assume that the element contains only the ^{69}Ga and ^{71}Ga isotopes.
Give your answer to **four** significant figures.

percentage abundance of ^{69}Ga = ... %
[2]

5 (c) Table 1.2 shows the relative abundances of isotopes in a sample of an alloy containing rhodium and iridium only.

Table 1.2

isotope	relative isotopic mass	relative abundance in alloy
$^{103}_{45}Rh$	102.91	50.00
$^{191}_{77}Ir$	190.96	15.18
$^{193}_{77}Ir$	192.96	34.82

(i) Define relative isotopic mass.

.....

.....

..... [2]

(ii) Use Table 1.2 to calculate the relative atomic mass, A_r, of iridium in the alloy.

Give your answer to **two** decimal places.

relative atomic mass of iridium = ... [2]

6 **(c)** The equation for the complete combustion of ethene is shown.

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

Calculate the volume, in dm^3, of carbon dioxide formed in the complete combustion of 1.00 g of ethene at room temperature and pressure.

volume of CO_2 = ... dm^3 [3]

7 **(b)** Ester **W** is made up of 54.5% carbon, 9.1% hydrogen and 36.4% oxygen.

(i) Calculate the empirical formula of **W**.

[3]

8 **(b)** Silicon is found in many compounds in the Earth's crust. Silicon has only three naturally occurring isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

(i) The table shows data for ^{28}Si, ^{29}Si and ^{30}Si.

	^{28}Si	^{29}Si	^{30}Si
relative isotopic mass	28.0	29.0	30.0

A sample of silicon contains 92.2% ^{28}Si. The total percentage abundance of ^{29}Si and ^{30}Si in the sample is 7.8%.

The relative atomic mass, A_r, of silicon in the sample is 28.09.

Calculate the percentage abundance of ^{30}Si.

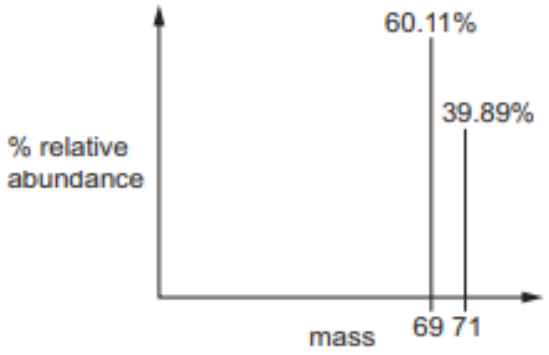
Give your answer to **one** decimal place.

percentage abundance of ^{30}Si = ... %

[3]

9 Gallium is an element in Group 13.

A sample of gallium is analysed using a mass spectrometer. The mass spectrum produced is shown.



(a) Explain what is meant by the term *relative atomic mass*.

.....

..... [2]

(b) Calculate the relative atomic mass of gallium in this sample. Give your answer to 4 significant figures.

Show your working.

relative atomic mass = ... [2]

(c) Complete the table which describes a gaseous atom of gallium.

isotope	nucleon number	total number of electrons in **lowest** energy level	type of orbital which contains the electron in the **highest** energy level
^{71}Ga			

[3]

1 A student reacts 4 mol of ammonia with oxygen to produce an oxide of nitrogen and water only. Each nitrogen atom increases its oxidation state by 5 in the reaction.

How many moles of oxygen gas react with 4 mol of ammonia in this reaction?

A 4 mol **B** 5 mol **C** 7 mol **D** 10 mol

2 A 3.0 g sample of Na_2CO_3 powder is stirred into 50 cm^3 of 1.0 mol dm^{-3} HC*l*. The volume of CO_2 produced is 600 cm^3.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

[M_r: Na_2CO_3, 106.0]

Which volume of CO_2 is produced if 1.0 g of Na_2CO_3 powder is stirred into 50 cm^3 of 1.0 mol dm^{-3} HC*l* under the same conditions?

A 600 cm^3 **B** 452 cm^3 **C** 226 cm^3 **D** 200 cm^3

3 Which sample contains the same number of the named species as the number of molecules in 35.5 g of chlorine?

A atoms in 16 g of sulfur

B atoms in 23 g of sodium

C ions in 74.5 g of potassium chloride

D molecules in 88 g of carbon dioxide

4 Sodium dichromate(VI), $Na_2Cr_2O_7$, reacts with hydrogen peroxide, H_2O_2, producing Cr^{3+} ions, water and oxygen.

What is the correctly balanced ionic equation for this reaction?

A $Cr_2O_7^{2-} + 2H^+ + H_2O_2 \rightarrow 2Cr^{3+} + 2H_2O + 4O_2$

B $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

C $Cr_2O_7^{2-} + 8H^+ + 6H_2O_2 \rightarrow 2Cr^{3+} + 10H_2O + 6O_2$

D $Cr_2O_7^{2-} + 14H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

5 Chlorine is bubbled through 100 cm^3 of hot 4.0 mol dm^{-3} sodium hydroxide until the reaction is complete.

$$6NaOH(aq) + xCl_2(aq) \rightarrow yNaCl(aq) + zNaClO_3(aq) + 3H_2O(l)$$

Which row is correct?

	x	$[Na^+](aq)$ after reaction / mol dm^{-3}
A	3	4.0
B	3	less than 4.0
C	6	4.0
D	6	less than 4.0

6 Which statement is correct?

A The relative atomic mass of a ^{35}Cl atom is 35.5.

B The relative formula mass of $CaCO_3$ is 100.1.

C The relative isotopic mass of a ^{24}Mg atom is 24.3.

D The relative molecular mass of O_2 is 16.0.

7 A sample of 35.6 g of hydrated sodium carbonate contains 25.84% sodium ions by mass.

When this sample is heated, anhydrous sodium carbonate and water are formed.

Which mass of water is given off?

A 7.2 g **B** 10.6 g **C** 14.4 g **D** 21.2 g

8 Sample X is added to water and made up to a total volume of 200 cm^3. This gives a solution of 0.100 mol dm^{-3} HCl.

What is X?

A 10 cm^3 of 1.00 mol dm^{-3} HCl

B 30 cm^3 of 0.90 mol dm^{-3} HCl

C 50 cm^3 of 0.40 mol dm^{-3} HCl

D 100 cm^3 of 0.30 mol dm^{-3} HCl

9 A mixture of 10 cm^3 of methane and 10 cm^3 of ethane was sparked with an excess of oxygen. After cooling, the residual gas was passed through aqueous potassium hydroxide.

All gas volumes were measured at the same temperature and pressure.

Which volume of gas was absorbed by the alkali?

A 15 cm^3 **B** 20 cm^3 **C** 30 cm^3 **D** 40 cm^3

10 Glauber's salt consists of crystals of hydrated sodium sulfate, $Na_2SO_4 \cdot xH_2O$, which can be used for the manufacture of detergents.

When a sample of Glauber's salt was heated, 1.91 g of water was removed leaving 1.51 g of anhydrous Na_2SO_4.

What is the value of x in $Na_2SO_4 \cdot xH_2O$?

A 1 **B** 8.85 **C** 10 **D** 11.25

11 What contains the greatest number of the named particles?

A 6.0 dm^3 of argon atoms at room conditions

B 6.0 g of carbon dioxide molecules

C 6.0 g of magnesium atoms

D 6.0 g of water molecules

12 7.5 g of nitrogen monoxide reacts with 7.0 g of carbon monoxide on the surface of the catalytic converter in the exhaust system of a car.

What is the total volume of the product gases measured at room conditions?

A 3.0 dm^3 **B** 6.0 dm^3 **C** 9.0 dm^3 **D** 12.0 dm^3

1

Question	Answer	Marks
1(a)(i)	**option 1** **M1** the mass of a molecule OR the (weighted) average / (weighted) mean mass of the molecule(s)	1
	option 1 and **M2** relative / compared to 1 / 12 (the mass) of **an atom** of carbon–12	1
	OR on a scale in which a carbon–12 atom / isotope has a mass of (exactly) 12 (units) **option 2** **M1** mass of one mol of molecules	
	option 2 **M2** relative / compared to 1 / 12 (the mass) of 1 mol of C-12 OR which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g	
1(a)(ii)	CO_2H	1
1(a)(iii)	$0.18/90 \times 2 \times 6.02 \times 10^{23} = 2.408 \times 10^{21}$ (atoms) OR **$2.4(1) \times 10^{21}$** (atoms) **M1** no mole ethanedioic acid $0.18 / 90 = 0.0020$	1
	M2 no mole ethanedioic acid $\times 2$ $0.0020 \times 2 = 0.0040$	1
	M3 no mole ethanedioic acid $\times 6.02 \times 10^{23}$ 2.4×10^{21}	1
1(b)(i)	$CaC_2O_4(s) \rightarrow CaO(s) + CO_2(g) + CO(g)$ **M1** correct formulae	1
	M2 balancing equation AND state symbols.	1
1(b)(ii)	(thermal) decomposition OR disproportionation	1
1(b)(iii)	calcium carbonate / $CaCO_3$	1

2

(d)(i)	**M1** moles of $As_2S_3 = 0.198 / 246.1 / 8.05 \times 10^{-4}$ **M2** moles SO_2 (using moles of As_2S_3 as limiting factor) $= 2.41(36) \times 10^{-3}$ moles $(6 / 2 \times 8.05 \times 10^{-4})$ Volume $SO_2 = 2.41(36) \times 10^{-3} \times 24 = 0.0579\ dm^3$ **M3** Moles O_2 used in reaction $= 8.05 \times 10^{-4} \times 9 / 2 = 3.62 \times 10^{-3}$ Volume O_2 used in reaction $= 3.62 \times 10^{-3} \times 24 = 0.0869\ dm^3$ **M4** Final total volume gas = $(0.1 - 0.0869) + 0.0579 =$ $[0.0131 + 0.0579] = \underline{0.071}(0)\ dm^3$ **M4 ONLY award 4th mark if the final answer rounds to <u>0.071</u>** Answer to minimum of 2 sig figs **MAX 3 for using** ecf from M1 to M2 to M3 and M4 **Award all 4 marks if final answer rounds to 0.071**	**4**
d)(ii)	acid rain	
(d)(iii)	**M1** $SO_2(g) + 2NaOH(aq) \rightarrow Na_2SO_3(aq) + H_2O(l)$ **AND** correct species and balancing **M2** State symbols	**2**

(e)(i)	1 / 12 (one twelfth) the mass of a carbon-12 / ^{12}C atom	**1**
(e)(ii)	**M1** correct expression relating A_r to the mass / % abundance of the three isotopes $24.31 = \boldsymbol{x} \times 0.7899 + 24.99 \times 0.1000 + 25.98 \times 0.1101$ **M2** correct answer to 4 sig figs atomic mass of **X** = 23.99	**2**
(e)(iii)	**M1** (magnesium isotopes have) identical chemical properties **AND** same electron(ic) arrangement / configuration **M2** different physical properties **AND** different number of neutrons	**2**

3

Question	Answer	Marks
(a)	**M1** % / A_r for C H O **M2** each % / A_r for C H O divided by the smallest value for % / Ar to give simplest whole number ratio / empirical formula **M3** compare M_r from **M2** ratio with 280 to deduce the actual molecular formula C: 77.2 / 12 = 6.433; 9(.03) H: 11.4 / 1 = 11.4; 16 O: 11.4 / 16 = 0.7125; 1 $M_r(C_9H_{16}O)$ = 140 so molecular formula of **V** = $C_{18}H_{32}O_2$	3
(b)(i)	**M1** (add) group 1 carbonate / group 1 bicarbonate / Na_2CO_3 / $NaHCO_3$ etc. **M2** effervescence / fizzing / bubbling	2
(b)(ii)	3.196 g Br_2 = 3.196 / 159.8 (= 0.02 mol Br_2) **AND** 2.8(00) / 280 (= 0.01 mol **V**) 2 alkene / 2 C=C (groups)	1

4

Question	Answer	Marks
(a)(i)	columns 1 & 3 identical *isotope* / *No of p's* / *No of n's* / *No of e's* ^{69}Ga / 31 / 38 / 31 ^{71}Ga / 31 / 40 / 31	1
	• √ √	1
(a)(ii)	**M1** (weighted) average / mean mass of the isotopes / average mass of the atom(s) (of an element)	1
	M2 compared to (the mass of) the unified atomic mass unit	1
(a)(iii)	$69.723 = 68.926x + 70.925(1-x) \therefore x = 0.6013$ / $69.723 = \frac{68.926x + 70.925(100-x)}{100}$	1
	60.13%	1

5

(c)	mass of an atom of an isotope	1
	compared to the mass of the unified atomic mass unit (amu) OR on a scale on which a carbon-12 atom has a mass of exactly 12 units OR divided by $\frac{1}{12}$ mass of a carbon-12 atom	1
(c)(ii)	$\frac{190.96 \times 15.18 + 192.96 \times 34.82}{50.00}$	1
	= **192.35**	1

6

Question	Answer		Marks
(c)	*method 1*	*method 2*	
M1	1 / 28 (= 0.035714)	1 : 88 / 28 (= 3.14286)	1
M2	2 × M1 (= 1 / 14 = 0.07143)	M1 / 44 (= 0.071429)	1
M3	M2 × 24 = 1.7 dm^3	M2 × 24 = 1.7 dm^3	1

7

Question	Answer			Marks
(b)(i)	**M1** *divide by A_r*	C 54.5 / 12	H 9.1 / 1	O 36.4 / 16	1
	M2 *divide by smallest number*	4.54 / 2.275 (= 2 OR 1.99)	9.1 / 2.275(=4)	2.275 / 2.275 (=1)	1
	M3 *empirical formula based on correctly rounded values of M2* C_2H_4O				1

8

Question	Answer	Marks
(b)(i)	**M1:** $\frac{(92.2 \times 28) + (^{29}\text{Si} \times 29) + (^{30}\text{Si} \times 30)}{100} = 28.09$ **M2:** (x =) 6.6 **OR** 28.09 = 28.078 + x (where x = abundance of Si-29) **M3:** *7.8 – M2 calculated correctly to one decimal place (or more)* (=) 1.2%	3

9

Question	Answer	Marks
(a)	**EITHER** **M1** (weighted) average/mean mass of the isotope(s)/an atom(s) **M2** relative to 1/12 of the mass (of an atom) of ^{12}C (where an atom of ^{12}C is exactly12). **OR** **M1** mass of one mol of atoms **M2** relative / compared to 1/12 (the mass) of 1 mol of C-12 OR in which one mol C-12 (atom) has a mass of (exactly) 12 g	2
(b)	**M1** 60.11/100 x 69 + 39.89/100x71 **M2** 69.80	2
(c)	isotope: ^{71}Ga; nucleon number: **M1** 71; total number of electrons in **lowest** energy level: **M2** 2; type of orbital contains the electron in the **highest** energy level: **M3** p (-orbital)	3

1)	B
2)	C
3)	A
4)	B
5)	B
6)	B
7)	C
8)	C
9)	C
10)	C
11)	D
12)	C