Atoms, molecules and stoichiometry – 2023 AS Chemistry 9701

1. Nov/2023/Paper_ 9701/11/No.1
   Sodium azide, NaN_3 is an explosive used to inflate airbags in cars when they crash. It consists of positive sodium ions and negative azide ions.

   What are the numbers of electrons in the sodium ion and the azide ion?

	sodium ion	azide ion
A	10	20
B	10	22
C	12	20
D	12	22

2. Nov/2023/Paper_ 9701/11/No.2
   The graph shows the variation of the first ionisation energy with proton number for some elements. The letters used are **not** the actual symbols for the elements.
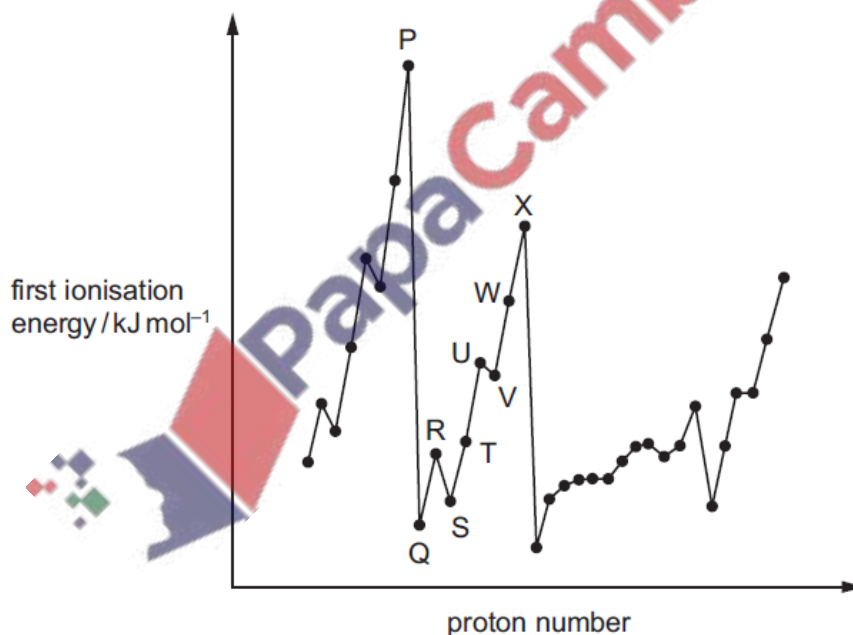
   Which statement about the elements is correct?

   A P and X are in the same period in the Periodic Table.

   B The general increase from Q to X is due to increasing atomic radius.

   C The small decrease from R to S is due to decreased shielding.

   D The small decrease from U to V is due to repulsion between paired electrons.

1

3. **Nov/2023/Paper_ 9701/11/No.3**

Aluminium carbide, Al_4C_3, reacts readily with aqueous sodium hydroxide. The two products of the reaction are $NaAlO_2$ and a hydrocarbon. Water molecules are also involved as reactants.

What is the formula of the hydrocarbon?

A CH_4 B C_2H_6 C C_3H_8 D C_6H_{12}

4. **Nov/2023/Paper_ 9701/11/No.4**

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

5. **Nov/2023/Paper_ 9701/12/No.1**

Which particle contains 8 protons, 9 neutrons and 10 electrons?

A $^{16}_{8}O^-$ B $^{16}_{8}O^{2-}$ C $^{17}_{8}O^-$ D $^{17}_{8}O^{2-}$

6. **Nov/2023/Paper_ 9701/12/No.2**

The second ionisation energy of oxygen is greater than the second ionisation energy of fluorine.

Which factor explains this difference?

A The atomic radius of an oxygen atom is smaller than that of fluorine.

B The covalent bond in a fluorine molecule is weaker than the bond in an oxygen molecule.

C A spin-paired electron is removed from fluorine but **not** from oxygen.

D Fluorine has more electrons in total than oxygen. This causes a greater shielding of the nuclear attraction in fluorine.

7. **Nov/2023/Paper_ 9701/12/No.3**

Zinc reacts with concentrated nitric acid giving three products only: zinc nitrate, an oxide of nitrogen and water.

3.0 moles of zinc react with 8.0 moles of nitric acid. Zinc nitrate contains Zn^{2+} ions.

What could be the formula of the oxide of nitrogen?

A N_2O B NO C N_2O_3 D NO_2

8.

A 3.7 g sample of copper(II) carbonate is added to 25 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

Which volume of gas is produced at room conditions?

A 0.60 dm^3 **B** 0.72 dm^3 **C** 1.20 dm^3 **D** 2.40 dm^3

9.

In an experiment, 0.100 mol of propan-1-ol is burnt completely in 12.0 dm^3 of oxygen, measured at room conditions.

What is the final volume of gas, measured at room conditions?

A 7.20 dm^3 **B** 8.40 dm^3 **C** 16.80 dm^3 **D** 18.00 dm^3

The elements phosphorus, sulfur and chlorine are in Period 3 of the Periodic Table.

Table 1.1 shows some properties of the elements P to Cl.

The first ionisation energy of S is **not** shown.

Table 1.1

property	P	S	Cl
number of electrons in 3p subshell			
total number of unpaired electrons			
first ionisation energy /kJ mol^{-1}	1060		1260
formula of most common anion	P^{3-}	S^{2-}	Cl^-

(a) (i) Complete Table 1.1 to show the number of electrons in the 3p subshell and the total number of unpaired electrons in an atom of P, S and Cl. [2]

(ii) Construct an equation to represent the first ionisation energy of P.

.... [1]

(iii) Three possible values for the first ionisation energy of S are given.

$1000\,kJ\,mol^{-1}$ $1160\,kJ\,mol^{-1}$ $1320\,kJ\,mol^{-1}$

Circle the correct value.

Explain your choice by comparing your chosen value to those of P and Cl.

....

....

....

....

.... [4]

4

(b) P^{3-}, S^{2-} and Cl^- have the same number of electrons.

  (i) Give the full electronic configuration of P^{3-}.

  .... [1]

  (ii) State the trend in ionic radius shown by P^{3-}, S^{2-} and Cl^-.

  Explain your answer.

  ....

  ....

  ....

  .... [2]

11. June/2023/Paper_9701/11/No.1

Element X has six more protons than element Y.

Which statement **must** be correct?

  A   Atoms of element Y are smaller than atoms of element X.

  B   Element X has a full shell of electrons.

  C   Element X and element Y are in the same group.

  D   Element X and element Y are in the same period.

12. June/2023/Paper_9701/11/No.2

Which statement explains why calcium has a higher melting point than barium?

  A   Calcium cations are smaller than barium cations and have a stronger attraction to the delocalised electrons.

  B   The structure of calcium is partly giant molecular.

  C   There are more delocalised electrons in calcium than in barium as it has a lower ionisation energy.

  D   There is greater repulsion between barium atoms as they have more complete electron shells than calcium atoms.

5

13. June/2023/Paper_9701/11/No.3

Three statements about potassium and chlorine and their ions are listed.

    1   The atomic radius of a potassium atom is greater than the atomic radius of a chlorine atom.

    2   The first ionisation energy of potassium is greater than the first ionisation energy of chlorine.

    3   The ionic radius of a potassium ion is greater than the ionic radius of a chloride ion.

Which statements are correct?

A   1 only   **B**   2 only   **C**   1 and 3   **D**   2 and 3

14. June/2023/Paper_9701/11/No.10

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.

15. June/2023/Paper_9701/12/No.1

When chlorine gas is analysed in a mass spectrometer $^{35}Cl^+$ ions are detected.

Which row is correct?

	number of neutrons in $^{35}Cl^+$	electronic configuration of $^{35}Cl^+$
A	17	$1s^2 2s^2 2p^6 3s^2 3p^4$
B	17	$1s^2 2s^2 2p^6 3s^2 3p^6$
C	18	$1s^2 2s^2 2p^6 3s^2 3p^4$
D	18	$1s^2 2s^2 2p^6 3s^2 3p^6$

16. June/2023/Paper_9701/12/No.2

Which species is a free radical?

A   He   **B** Be^- **C** O^{2-} **D**   Zn

17. June/2023/Paper_9701/12/No.3

Which statement is correct?

A   The first ionisation energy of chlorine is more than the first ionisation energy of argon.

B   The second ionisation energy of calcium is more than the second ionisation energy of magnesium.

C   The second ionisation energy of sulfur is equal to the first ionisation energy of phosphorus.

D   The eighth ionisation energy of chlorine is more than the first ionisation energy of neon.

18. June/2023/Paper_9701/12/No.4

If 1 mole of hexane combusts in an excess of oxygen, how many moles of products are formed?

A   11   B   12   C   13   D   14

19. June/2023/Paper_9701/12/No.5

Separate samples, each of mass 1.0 g, of the compounds listed are treated with an excess of dilute acid.

Which compound releases the largest amount of CO_2?

A   1.0 g $CaCO_3$ B   1.0 g Li_2CO_3 C   1.0 g $MgCO_3$ D   1.0 g Na_2CO_3

20. June/2023/Paper_9701/13/No.3

A piece of rock has a mass of 2.00 g. It contains calcium carbonate, but no other basic substances. It neutralises exactly 36.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid.

What is the percentage by mass of calcium carbonate in the 2.00 g piece of rock?

A   22.5%   B   45.0%   C   72.0%   D   90.1%

21. June/2023/Paper_9701/13/No.11

Which mixture will react to form exactly one mole of water?

	volume 2.00 mol dm^{-3} H_2SO_4 / cm^3	volume 1.00 mol dm^{-3} NaOH / cm^3
A	250	500
B	250	1000
C	500	500
D	500	1000

Tellurium is an element in Group 16. The most common isotope of tellurium is ^{130}Te. Its electronic configuration is [Kr] $4d^{10}$ $5s^2$ $5p^4$.

(a) Complete Table 1.1.

Table 1.1

	nucleon number	number of neutrons	number of electrons
^{130}Te			

[3]

(b) Identify the sub-shell in an atom of Te that contains electrons with the lowest energy.

.... [1]

(c) Construct an equation to represent the first ionisation energy of Te.

.... [1]

(d) **(i)** The radius of Te ions decreases after each successive ionisation.

State **two** factors that are responsible for the increase in the first six ionisation energies of Te.

....

....

.... [2]

(ii) Sketch a graph in Fig. 1.1 to show the trend in the first **seven** ionisation energies of Te.

ionisation
energy / kJ mol^{-1}

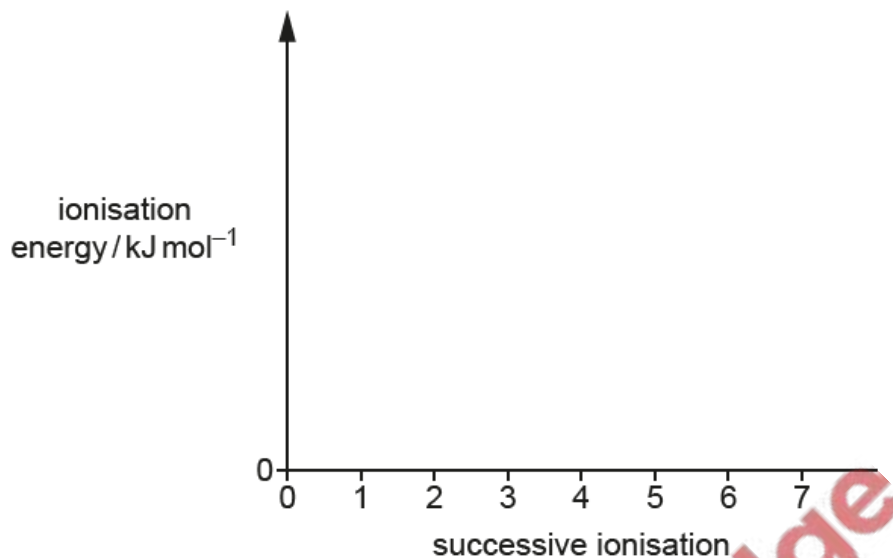**Fig. 1.1**

[2]

(e) Te reacts with F_2 at 150 °C to form TeF_x. Molecules of TeF_x are octahedral with bond angles of 90°.

Explain why TeF_x is octahedral with bond angles of 90°.

....

....

.... [2]

(f) TeF_x reacts with water to form tellurium hydroxide and HF. The oxidation number of tellurium does **not** change during this reaction.

(i) Construct an equation for the reaction of TeF_x with water.

.... [1]

(ii) Name the type of reaction that occurs when TeF_x reacts with water.

.... [1]

[Total: 13]

Copper is used in electrical equipment. It has a melting point of 1085 °C.

(a) (i) Identify the lattice structure of copper.

.... [1]

(ii) Draw a labelled diagram to show the bonding present in copper.

[1]

(b) The relative isotopic masses and natural abundances of the two isotopes in a sample of copper are shown in Table 1.1.

Table 1.1

isotope	relative isotopic mass	% abundance
^{63}Cu	62.930	69.15
^{65}Cu	64.928	30.85

(i) Define the unified atomic mass unit.

....

.... [1]

(ii) Define relative atomic mass, A_r, in terms of the unified atomic mass unit.

....

.... [1]

(iii) Calculate the relative atomic mass, A_r, of copper in this sample using the data in Table 1.1.

Show your working.

A_r = ... [1]

(c) The mass spectrum of a sample of pure copper is shown in Fig. 1.1.
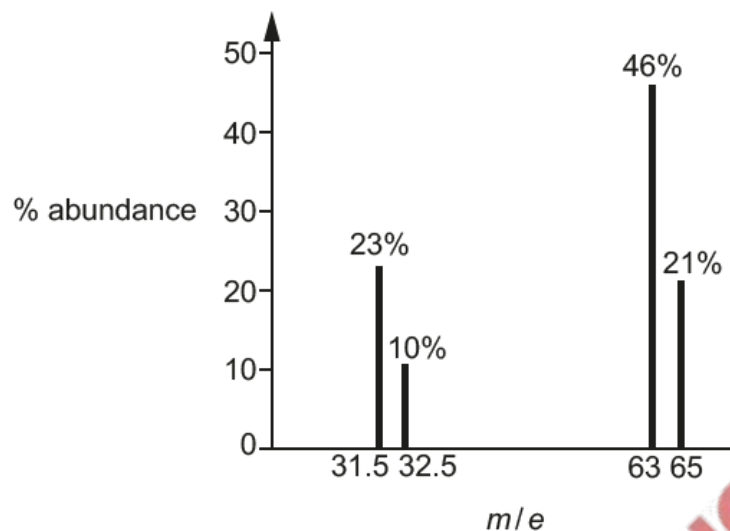
Fig. 1.1

Identify the ion with an abundance of 23% in the sample.

.... [1]

(d) When KI(aq) is added to $CuSO_4$(aq) the blue-coloured solution turns brown and a white precipitate of CuI(s) is seen.

The reaction between copper ions and iodide forms only two products.

(i) Complete the equation for this reaction.

............Cu^{2+} + ...I^- → ....CuI + ...

[1]

(ii) Identify the oxidising agent in this reaction. Explain your answer in terms of electron transfer.

....

.... [1]
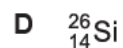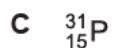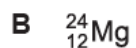
(iii) State the full electronic configuration of Cu^{2+}.

.... [1]

[Total: 9]

24.

Which atom contains four times as many neutrons as the $^{7}_{3}Li$ atom?

A $^{40}_{20}Ca$ **B** $^{24}_{12}Mg$ **C** $^{31}_{15}P$ **D** $^{26}_{14}Si$
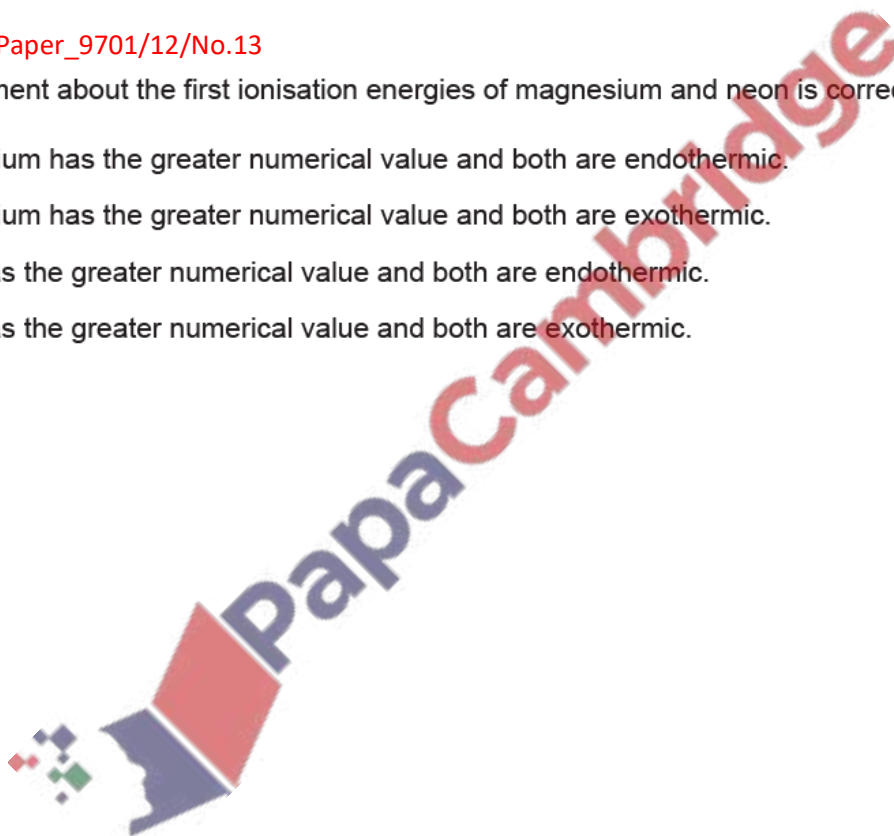
25.
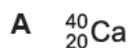
Which statement about the first ionisation energies of magnesium and neon is correct?

A Magnesium has the greater numerical value and both are endothermic.

B Magnesium has the greater numerical value and both are exothermic.

C Neon has the greater numerical value and both are endothermic.

D Neon has the greater numerical value and both are exothermic.

26.

Hydrated cobalt(II) sulfate loses water when heated to give anhydrous cobalt(II) sulfate. All the water of crystallisation is lost to the atmosphere as steam.

When 3.10 g of hydrated cobalt(II) sulfate, $CoSO_4 \cdot xH_2O$, is heated to constant mass the **loss** in mass is 1.39 g.

What is the value of x, to the nearest whole number?

A 4 **B** 6 **C** 7 **D** 11

The Pauling electronegativity values of elements can be used to predict the chemical properties of compounds.

Use the information in Table 1.1 to answer the following questions.

Table 1.1

element	H	Li	C	O	S
Pauling electronegativity value	2.1	1.0	2.5	3.5	2.6
first ionisation energy/kJ mol^{-1}	1310	519	1090	1310	1000
second ionisation energy/kJ mol^{-1}	—	7300	2350	3390	2260

(a) (i) Define electronegativity.

....

.... [1]

(ii) O and S are in Group 16.

Explain the difference in the Pauling electronegativity values of O and S.

....

....

.... [2]

(b) (i) LiH is an ionic compound.

Draw a dot-and-cross diagram of LiH.

Include **all** electrons.

[2]

(ii) Suggest the shape of a molecule of H_2S.

.... [1]

(c) (i) Write an equation that represents the first ionisation energy of H.

.... [1]

(ii) Explain why there is no information given in Table 1.1 for the second ionisation energy of H.

.... [1]

(iii) Give the full electronic configuration of $S^{2+}(g)$.

.... [1]

(d) CO_2 and SO_2 are acidic gases.

(i) Write an equation for the reaction of SO_2 with H_2O.

.... [1]

(ii) Write an equation for the reaction of SO_2 with NaOH.

.... [1]

(iii) Construct an equation for the reaction of CO_2 with $Mg(OH)_2$.

.... [1]
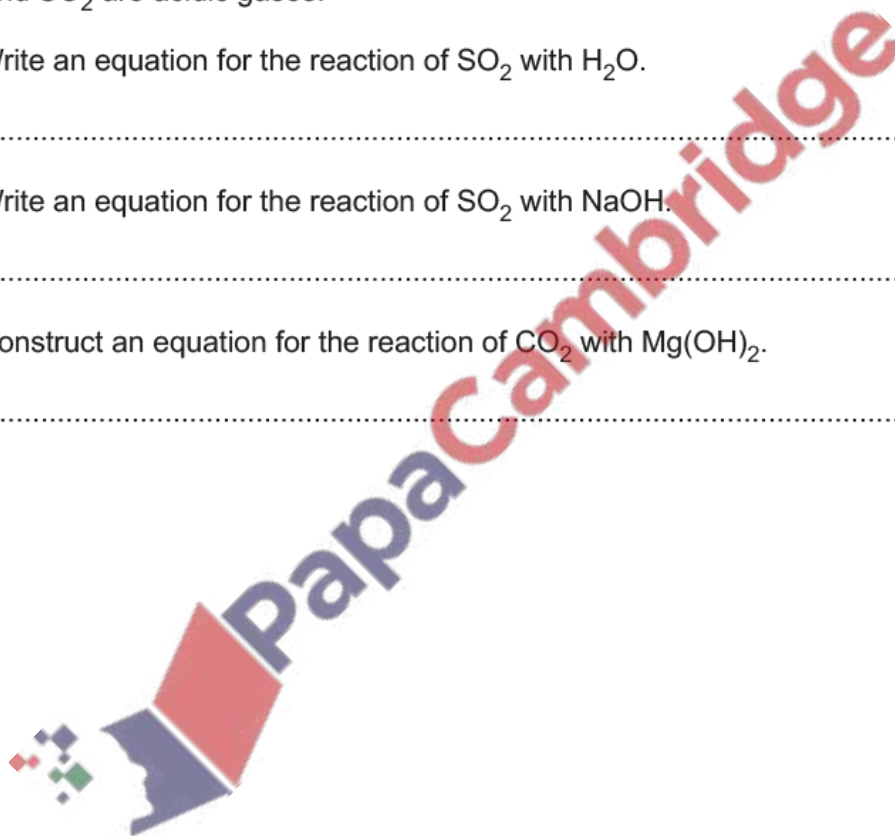
(e) (i) Complete Table 1.2 by placing a tick (✓) to show which of the compounds have molecules with an overall dipole moment.

Table 1.2

compound	O=C=O	O=S=O	S=C=S	S=C=O
overall dipole moment				

[2]

(ii) At 150 °C and 103 kPa, all of the compounds listed in Table 1.2 are gases.

Under these conditions, 0.284 g of one of the compounds occupies a volume of 127 cm³.

Use this information to calculate the M_r of the compound. Hence, identify the compound from those given in Table 1.2.

Show your working.

M_r = ... identity of compound = ...

[3]

[Total: 17]