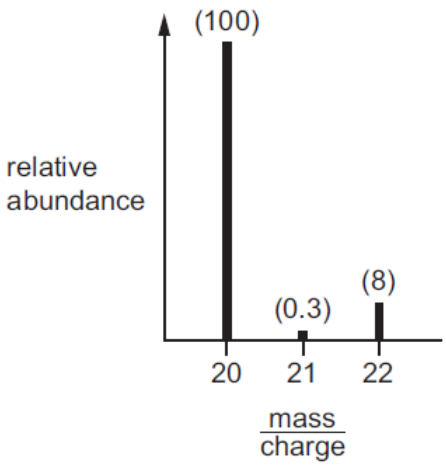
# Atoms, molecules and stoichiometry – 2021 AS

**1.** Nov/2021/Paper_11/No.1

The mass spectrum of a sample of neon is shown. The relative abundance of each peak is written in brackets above it.




What is the relative atomic mass, $A_r$, of this sample of neon?

**A** 20.15 **B** 20.20 **C** 21.00 **D** 21.82

**2.** Nov/2021/Paper_11/No.2

2.0 g of ammonium nitrate, $NH_4NO_3$, decomposes to give 0.90 g of water and a single gas.

What is the identity of the gas?

**A** NO **B** $NO_2$ **C** $N_2O$ **D** $N_2$

**3.** Nov/2021/Paper_11/No.3

Which of these elements has the highest fifth ionisation energy?

**A** C **B** N **C** P **D** Si

**4.** Nov/2021/Paper_11/No.4

The ion $X^{2+}$ has the same electronic configuration as the atom Kr.

What is the electronic configuration of an atom of X?

**A** $[Ar]4s^23d^{10}4p^6$

**B** $[Ar]4s^23d^{10}4p^65s^2$

**C** $[Ar]4s^24d^{10}4p^6$

**D** $[Ar]4s^24d^{10}4p^65s^2$

**5.** Nov/2021/Paper_11/No.12

Which element requires the least number of moles of oxygen for the complete combustion of 1 mol of its atoms?

**A** aluminium

**B** magnesium

**C** phosphorus

**D** sodium

**6.** Nov/2021/Paper_12/No.1

Compound X consists of 40.0% carbon, 6.7% hydrogen and 53.3% oxygen by mass.

What is the empirical formula of compound X?

**A** $CH_2O$ **B** $C_2H_2O$ **C** $C_2H_4O$ **D** CHO

**7.** Nov/2021/Paper_12/No.2

Which statement is correct?

**A** 1.0 g of hydrogen gas contains $3.0 \times 10^{23}$ atoms.

**B** 4.0 g of helium gas contains $1.2 \times 10^{24}$ atoms.

**C** 16 g of methane gas contains $3.0 \times 10^{24}$ atoms.

**D** 44 g of carbon dioxide gas contains $6.0 \times 10^{23}$ atoms.

**8.** Nov/2021/Paper_12/No.3

Technetium (Tc) is a second row transition element that does not occur naturally on Earth. One of its isotopes has 56 neutrons.

What is the nucleon number of this isotope?

**A** 43 **B** 56 **C** 99 **D** 112

**9.** Nov/2021/Paper_12/No.4

Which atom has more unpaired electrons than paired electrons in orbitals of principal quantum number 2?

**A** carbon

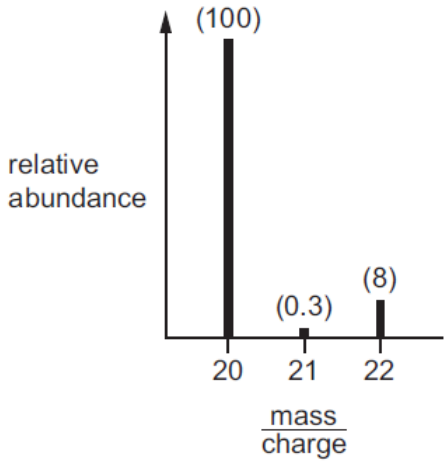
**B** nitrogen

**C** oxygen

**D** fluorine

**10.** Nov/2021/Paper_13/No.1

The mass spectrum of a sample of neon is shown. The relative abundance of each peak is written in brackets above it.




What is the relative atomic mass, $A_r$, of this sample of neon?

**A** 20.15 **B** 20.20 **C** 21.00 **D** 21.82

**11.** Nov/2021/Paper_13/No.2

2.0 g of ammonium nitrate, $NH_4NO_3$, decomposes to give 0.90 g of water and a single gas.

What is the identity of the gas?

**A** NO **B** $NO_2$ **C** $N_2O$ **D** $N_2$

**12.** Nov/2021/Paper_13/No.3

Which of these elements has the highest fifth ionisation energy?

**A** C **B** N **C** P **D** Si

**13.** Nov/2021/Paper_13/No.4

The ion $X^{2+}$ has the same electronic configuration as the atom Kr.

What is the electronic configuration of an atom of X?

**A** $[Ar]4s^23d^{10}4p^6$

**B** $[Ar]4s^23d^{10}4p^65s^2$

**C** $[Ar]4s^24d^{10}4p^6$

**D** $[Ar]4s^24d^{10}4p^65s^2$

**14.** Nov/2021/Paper_13/No.7

In order to determine the enthalpy of neutralisation of a strong acid and a strong alkali, 25.0 $cm^3$ of 2.00 mol $dm^{-3}$ sodium hydroxide is added to 25.0 $cm^3$ of 2.00 mol $dm^{-3}$ hydrochloric acid. The increase in temperature is 12 °C.

In a second experiment, the same method is used, but 50.0 $cm^3$ of 2.00 mol $dm^{-3}$ sodium hydroxide is added to 50.0 $cm^3$ of 2.00 mol $dm^{-3}$ hydrochloric acid.

What is the increase in temperature in the second experiment?

**A** 6 °C **B** 12 °C **C** 24 °C **D** 48 °C

**15.** Nov/2021/Paper_13/No.12

Which element requires the least number of moles of oxygen for the complete combustion of 1 mol of its atoms?

**A** aluminium

**B** magnesium

**C** phosphorus

**D** sodium

**16.** Nov/2021/Paper_21/No.1(d)

**(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]

**17.** March/2021/Paper_12/No/.1

The table shows the numbers of protons, neutrons and electrons in four different particles, W, X, Y, and Z.

| | number of protons | number of neutrons | number of electrons |
|---|---|---|---|
| W | 32 | 40 | 32 |
| X | 32 | 40 | 34 |
| Y | 32 | 42 | 32 |
| Z | 34 | 40 | 34 |

Which pair represents the atoms of two isotopes of the same element?

**A** W and Y **B** W and Z **C** X and Y **D** X and Z

**18.** March/2021/Paper_12/No/.2

Where in the Periodic Table is the element that has an outer electron shell arrangement of $4s^2 4p^3$?

| | Group | Period |
|---|---|---|
| **A** | 13 | 3 |
| **B** | 13 | 4 |
| **C** | 15 | 3 |
| **D** | 15 | 4 |

**19.** March/2021/Paper_12/No/.3

Substance Q is a hydrocarbon. When 1.00 g of Q is completely burned, 3.22 g of carbon dioxide is produced.

What could be the identity of Q?

**A** cyclohexene

**B** cyclopentane

**C** ethene

**D** pentane

**20.** March/2021/Paper_12/No/.4

Originally, chemists thought indium oxide had the formula InO. By experiment they showed that 4.8 g of indium combined with 1.0 g of oxygen to produce 5.8 g of indium oxide. The $A_r$ of oxygen was known to be 16.

Which value for the $A_r$ of indium is calculated using these data?

**A** 38 **B** 77 **C** 115 **D** 154

**21.** March/2021/Paper_12/No/.6

A solution contains 0.25 g of sulfur dioxide in 1.00 $dm^3$ of water.

Which volume of sulfur dioxide, measured at 50 °C and a pressure of $1 \times 10^5$ Pa, must be added to 1.00 $dm^3$ of water to produce this solution?

**A** 0.0162 $cm^3$ **B** 0.105 $cm^3$ **C** 16.2 $cm^3$ **D** 105 $cm^3$

**22.** March/2021/Paper_12/No/.13

Which row is correct?

| | statement | reason |
|---|---|---|
| **A** | The first ionisation energy of phosphorus is greater than that of magnesium. | electron is lost from a 3p orbital in both cases |
| **B** | The melting point of phosphorus is greater than that of magnesium. | phosphorus has more valence electrons than magnesium |
| **C** | The atomic radius of phosphorus is smaller than that of magnesium. | phosphorus has greater nuclear charge than magnesium |
| **D** | The electrical conductivity of phosphorus is smaller than that of magnesium. | bonding changes from ionic in magnesium to covalent in phosphorus |

**23.** March/2021/Paper_12/No/.35

A sample containing $x$ mol of $Al_2Cl_6$ is dissolved in water to give solution W.

In order to precipitate all of the aluminium as its hydroxide, $y$ mol of sodium hydroxide are required.

More of the alkali is added to re-dissolve the precipitate, giving solution Z.

Which statements are correct?

**1** the initial pH of solution W is below 7

**2** $y = 3x$

**3** Z contains $x$ mol of aluminium

**24.** June/2021/Paper_11/No.1

Which contains the largest number of hydrogen atoms?

**A** 0.10 mol of pentane

**B** 0.20 mol of but-2-ene

**C** 1.00 mol of hydrogen molecules

**D** $6.02 \times 10^{23}$ hydrogen atoms

**25.** June/2021/Paper_11/No.2

In which pair of species do both species have only one unpaired p electron?

**A** $Ar^+$ and $C^-$ **B** B and $Ti^+$ **C** F and Ga **D** $Se^-$ and $Si^-$

**26.** June/2021/Paper_11/No.6

What is the minimum mass of oxygen required to ensure the complete combustion of 12 $dm^3$ of propane measured under room conditions?

**A** 60 g **B** 80 g **C** 120 g **D** 160 g

**27.** June/2021/Paper_11/No.7

Why is the first ionisation energy of oxygen less than that of nitrogen?

**A** The nitrogen atom has its outer electron in a different subshell.

**B** The nuclear charge on the oxygen atom is greater than that on the nitrogen atom.

**C** The oxygen atom has a pair of electrons in one p orbital that repel one another.

**D** There is more shielding in an oxygen atom.

**28.** June/2021/Paper_12/No.1

Which statement about the Avogadro constant is correct?

**A** It is the mass of one mole of any element.

**B** It is the mass of $6.02 \times 10^{23}$ atoms of any element.

**C** It is the number of atoms in one mole of neon.

**D** It is the number of atoms in 12 g of any element.

**29.** June/2021/Paper_12/No.2

Which equation represents the first ionisation energy of iodine?

**A** $\frac{1}{2}I_2(g) + e^- \rightarrow I^-(g)$

**B** $I(g) + e^- \rightarrow I^-(g)$

**C** $\frac{1}{2}I_2(g) \rightarrow I^+(g) + e^-$

**D** $I(g) \rightarrow I^+(g) + e^-$

**30.** June/2021/Paper_12/No.31

In which ions are the number of electrons equal to the number of neutrons?

1 $^{19}_{9}F^-$

2 $^{31}_{15}P^-$

3 $^{23}_{11}Na^+$

**31.** June/2021/Paper_13/No.1

Compound X is an organic compound that contains 30.6% carbon, 3.8% hydrogen, 20.4% oxygen and 45.2% chlorine by mass.

What is the empirical formula of X?

**A** $C_2H_3OCl$ **B** $C_2H_4OCl$ **C** $C_3H_4OCl$ **D** $C_4H_3O_2Cl_2$

**32.** June/2021/Paper_13/No.2

A sample of propane, $C_3H_8$, with a mass of 9.61 g is completely combusted in an excess of oxygen under room conditions.

Which volume of carbon dioxide gas is produced?

**A** 4.89 $dm^3$ **B** 5.24 $dm^3$ **C** 14.7 $dm^3$ **D** 15.7 $dm^3$

**33.** June/2021/Paper_13/No.3

Which atom has the same number of electrons as an ammonium ion?

**A** Mg **B** Na **C** Ne **D** O

**34.** June/2021/Paper_13/No.9

Copper dissolves in dilute nitric acid producing a blue solution of $Cu(NO_3)_2$, water and nitrogen(II) oxide as the only products.

How many moles of acid react with three moles of copper in the balanced equation?

**A** 2 **B** 4 **C** 6 **D** 8

**35.** June/2021/Paper_13/No.31

Which statements about first ionisation energies are correct?

1 They are always endothermic.

2 They decrease down Group 2.

3 They decrease across Period 3.

**36.** June/2021/Paper_13/No.34

Element X is a solid under room conditions. It occurs as a contaminant of fossil fuels.

Its oxide, Y, is formed when fossil fuels are burned.

In the atmosphere, Y can be further oxidised to Z.

Which statements about X, Y and Z are correct?

**1** Atoms of X have paired p electrons.

**2** The atmospheric oxidation of Y to Z is a catalysed reaction.

**3** With water, Z forms a strong acid.

**37.** June/2021/Paper_21/No.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]

**38.** June/2021/Paper_23/No.1(e)

**(e)** The concentration of NaC*l*O in bleach **S** is $x\,g\,dm^{-3}$.

NaC*l*O reacts with $H_2O_2(aq)$ as shown.

$$H_2O_2(aq) + NaClO(aq) \rightarrow H_2O(l) + NaCl(aq) + O_2(g)$$

A $5.00\,cm^3$ sample of **S** completely reacts with $H_2O_2(aq)$. The volume of $O_2(g)$ produced is $24.0\,cm^3$ under room conditions.

Assume that only the NaC*l*O in **S** reacts with $H_2O_2(aq)$.

Calculate *x*. Show your working.

*x* = ..... $g\,dm^{-3}$

[3]