WESTMINSTER SCHOOL
THE CHALLENGE 2024

CHEMISTRY

Thursday 2 May 2024
Time allowed: 30 minutes

Instructions to candidates:

This paper has **three** questions.
You should answer **all** questions
There are 33 marks available.

The marks for individual questions and parts of questions are shown in square brackets [ ]. **Calculators are allowed.** Any data needed will be given in the questions.

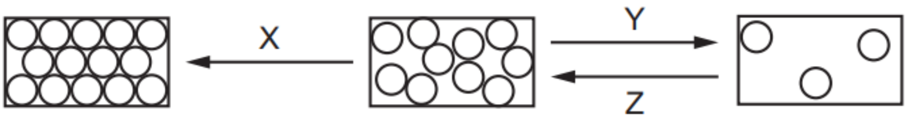
Please write in black or blue ink.
Write your answers in the spaces provided.
For examiner use only

Total Mark	

C1. This question is about some general chemistry.

Circle the letter that corresponds to your chosen answer.

a) The three rectangles show the arrangements of the particles in each of the three states of matter. X, Y and Z represent the processes needed to change one state to another.



What are the processes X, Y and Z?

	X	Y	Z
A	melting	condensing	evaporating
B	evaporating	melting	freezing
C	melting	freezing	condensing
D	freezing	evaporating	condensing

b) Which of the following processes involves a **chemical** change?

A Boiling water

B Producing water from sodium chloride solution

C Burning wood

D Dissolving salt in water

c) Elements **W** and **X** are metals. Elements **Y** and **Z** are non-metals. The oxides of **W**, **X**, **Y** and **Z** all form solutions when added to water.

Which statement is correct?

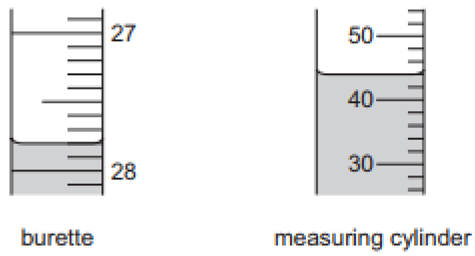
A The solution of the oxide of element **W** turns blue litmus red.

B The solution of the oxide of element **X** fizzes when sodium carbonate is added.

C The solution of the oxide of element **Y** has a pH greater than pH 7.

D The solution of the oxide of element **Z** fizzes when powdered magnesium is added.

d) The diagrams show liquids in a burette and a measuring cylinder.



Which row shows the correct readings for the burette and the measuring cylinder?

	Burette	Measuring cylinder
A	27.8	42
B	27.8	44
C	28.2	42
D	28.2	44

e) 2g of a gas is combusted in pure oxygen to produce 18g of a colourless liquid as the only product. What mass of oxygen has reacted?

A 2g

B 16g

C 18g

D Not enough information to calculate

[Total: 5]

C2. This question is about bronze.

Award trophies are often made of bronze rather than a pure metal as it is cheaper to manufacture. Bronze is an alloy (mixture) of copper and tin. Typically, raw materials would cost around £20 for a reasonably sized trophy.

By comparison, the FIFA World Cup is made of solid silver that is coated in gold – costing over £3,000 in raw material. The density of silver is 10.5 g/cm^3.

a) Outline a physical test that would indicate that a sample of bronze was metallic.

………

………

[2]

b) Bronze is chosen as a suitable material over copper because pure copper reacts with oxygen and carbon dioxide in the atmosphere to form copper carbonate. When heated, copper carbonate thermally decomposes to form copper oxide and carbon dioxide.

(i) State the colour of copper carbonate.

……

[1]

(ii) Define the term **thermal decomposition**.

……

……

[2]

(iii) Describe what would be observed when a sample of solid copper carbonate is heated.

……

……

[1]

(iv) Give a chemical test for carbon dioxide.

……

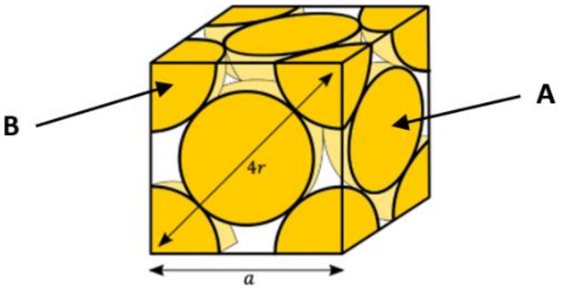
……

……

[2]

c) Bronze generally has the same structure as pure copper.

The **unit cell** of this structure is shown in the diagram on the right. This represents the simplest repeating unit which describes the structure as a whole.



In this diagram, atoms are shared between neighbouring unit cells. For example, on each face of the cube (labelled **A**) there is half of one atom inside the unit cell (the other half is in the adjoining unit cell). Atoms on the corner (labelled **B**) are shared with more than one other unit cell. The unit cell is symmetrical.

The radius of a copper atom, r, is 1.28×10^{-12} cm. The length of the diagonal across the face of the unit cell is $4r$.

(i) Calculate the length of one side of the unit cell, a, and hence the volume of the unit cell.

a = ……………………………………………… cm

Volume of unit cell = ………………………………………………cm^3

[2]

(ii) Deduce how much of each corner atom (**B**) is inside the unit cell.

………

[1]

(iii) Hence, deduce how many equivalent atoms there are in total within one unit cell.

………

[1]

(iv) The mass of one atom of copper is 1.05×10^{-22} g. Using your answers for (i) – (iii), calculate the density of copper in g/cm^3.

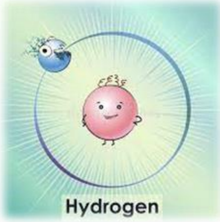
*[N.B. if you were unable to get an answer to (iii), use the value 6 for part (iv) – this is **not** the correct answer]*

Density = ………………………………….. g/cm^3

[3]

[Total: 15]

C3. This question is about counting electrons.



It is often said that chemistry is all about electrons – a reaction involves the movement of electrons from one atom to another, or the sharing of electrons, to form a bond. Electrons can never be created or destroyed during a reaction, so we know that at all stages all electrons must be accounted for.

If an atom has the same total number of electrons as its atomic number (found in the Periodic Table), it is a neutral atom – this is because the number of protons in the nucleus (positive) is equal to the number of electrons (negative). If the number of electrons is not the same, then a **charged ion** will form. Protons and electrons have equal but opposite charges – each electron is –1 and each proton is +1.

Only electrons in the outer shell of an atom (the **valence electrons**) are involved in bonding. The number of valence electrons for a neutral atom is equal to the Group Number in the Periodic Table. You should refer to the section of the Periodic Table below to help answer the questions that follow.

Group 1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
H							He
Li	Be	B	C	N	O	F	Ne
Na	Mg	Al	Si	P	Se	Cl	Ar
K	Ca	Ga	Ge	As	Se	Br	Kr

a) Fill in the table to show how many valence electrons each of the following atoms has.

Chlorine, Cl	…………………………………
Calcium, Ca	…………………………………

[2]

b) Fill in the table to show how many valence electrons each of the following ions has.

S^{2-}	…………………………………
O^{+}	…………………………………
B^{3+}	…………………………………
Na^{-}	…………………………………

[2]

c) Elements in Group 8 of the Periodic table have a full valence shell of electrons. The next element (i.e. group 1 in the row below) then starts a *new* shell. Helium (He), for example, therefore only has one shell of electrons.

(i) State how many electron shells an atom of aluminium (Al) has.

……

[1]

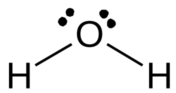
(ii) State how many electron shells a soium ion (Na^+) has.

……

[1]

In the drawing of molecules, a line represents electrons that are shared between each atom. Each atom involved provides one electron from its valence electrons, resulting in a shared pair of electrons – this is known as a covalent bond.

For example, water (H_2O) can be drawn as follows:



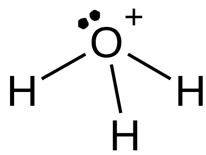
In this diagram, the oxygen atom (which has 6 valence electrons) has provided one electron to each bond with a hydrogen atom (shown by the line). This leaves 4 electrons that are not bonded – shown as **lone pairs** in the diagram (the molecule above therefore has **two** lone pairs).

d) Draw the following molecules in the same way:

Silane, SiH_4	
Ammonia, NH_3	

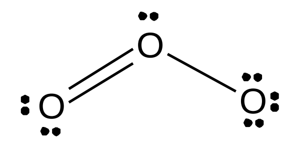
[2]

In molecules, individual atoms may often be shown with charges, such as the oxygen in H_3O^+ shown below. Such charges are known as **formal charges**.



If it is assumed that each bond (the lines) represents a pair of electrons shared equally between two atoms, the oxygen atom has 3 electrons used in bonds to the hydrogen atoms (3 lines) and two electrons left over (the lone pair) – so 5 electrons in total. A neutral oxygen atom has 6 valence electrons, so formally, the oxygen atom in H_3O^+ has a charge of +1.

e) Add the formal charges to the non-neutral atoms in the following structure (all lone pairs have been shown). A double bond is represented by two lines, using 2 valence electrons from each atom.

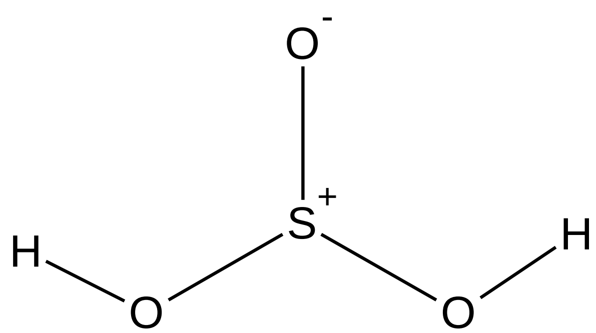


Ozone

[2]

f) In practice, formal charges would usually be shown on a structure, and this could then be used to calculate the number of lone pairs atoms would have.

Add all the lone pairs to the atoms in the following structure.



Sulphurous acid

[3]

[Total: 13 marks]