1 It was reported from America that a turbine engine, the size of a button, might replace batteries. The engine would be built from silicon which has suitable properties for this purpose.

(a) Why are batteries a convenient source of energy?

.....

[1]

(ii) The engine will run on a small pack of jet fuel. What other chemical is needed to burn this fuel?

.....

[1]

(b) Silicon has the same type of macromolecular structure as diamond.

(i) Explain why one atom of either element can form four covalent bonds.

.....

.....

[2]

(ii) Predict **two** physical properties of silicon.

.....

.....

[2]

(iii) Name a different element that has a similar structure and properties to silicon.

.....

[1]

(c) Silicon is made by the carbon reduction of the macromolecular compound, silicon(IV) oxide.

(i) Balance the equation for the reduction of silicon(IV) oxide.

SiO_2 + ... C $\rightarrow$ Si + ... CO [1]

(ii) Explain why the silicon(IV) oxide is said to be reduced.

.....

[1]

(iii) Describe the structure of silicon(IV) oxide. You may use a diagram.

.....

[2]

2 Calcium and other minerals are essential for healthy teeth and bones. Tablets can be taken to provide these minerals.

Healthy Bones

Each tablet contains

calcium
magnesium
zinc
copper
boron

(a) Boron is a non-metal with a macromolecular structure.

(i) What is the valency of boron?

.....

(ii) Predict **two** physical properties of boron.

.....

.....

(iii) Name another element and a compound that have macromolecular structures.

element ……..

compound ……

(iv) Sketch the structure of one of the above macromolecular substances.

[7]

(b) Describe the reactions, if any, of zinc and copper(II) ions with an excess of aqueous sodium hydroxide.

(i) zinc ions

addition of aqueous sodium hydroxide .....

.....

excess sodium hydroxide .....

.....

(ii) copper(II) ions

addition of aqueous sodium hydroxide .....

.....

excess sodium hydroxide .....

.....[4]

(c) Each tablet contains the same number of moles of $CaCO_3$ and $MgCO_3$. One tablet reacted with excess hydrochloric acid to produce 0.24 dm^3 of carbon dioxide at r.t.p.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + {}_2O$$
$$MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + {}_2O$$

(i) Calculate how many moles of $CaCO_3$ there are in one tablet.

number of moles CO_2 = ...

number of moles of $CaCO_3$ and $MgCO_3$ = ...

number of moles of $CaCO_3$ = ...

[3]

(ii) Calculate the volume of hydrochloric acid, 1.0 mol / dm^3, needed to react with one tablet.

number of moles of $CaCO_3$ and $MgCO_3$ in one tablet = ...
Use your answer to **(c)(i)**.

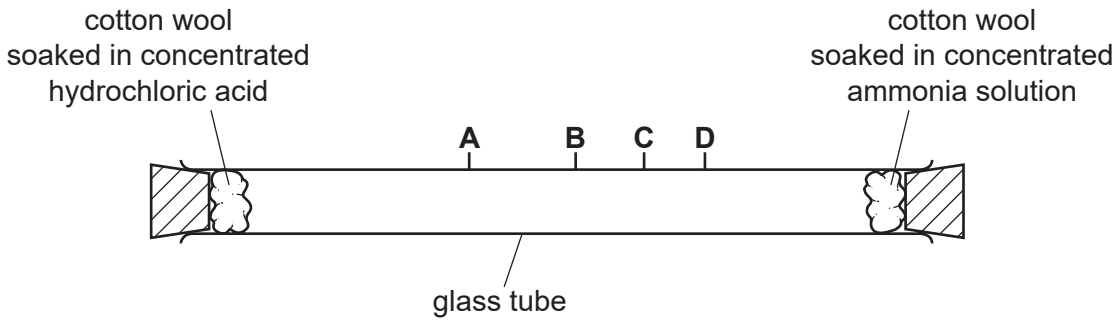
number of moles of HCl needed to react with one tablet = ...

volume of hydrochloric acid, 1.0 mol / dm^3, needed to react with one tablet = ...

[2]

3 Concentrated ammonia solution gives off ammonia gas. Concentrated hydrochloric acid gives off hydrogen chloride gas. Ammonia, NH_3, and hydrogen chloride, HCl, are both colourless gases. Ammonia reacts with hydrogen chloride to make the white solid ammonium chloride.

Apparatus is set up as shown.



After ten minutes a white solid forms in the tube where the gases meet.

(a) (i) Write the chemical equation for the reaction of ammonia with hydrogen chloride.

..... [1]

(ii) Name the process by which the ammonia and hydrogen chloride gases move in the tube.

..... [1]

(iii) At which point, **A**, **B**, **C** or **D**, does the white solid form? Explain why the white solid forms at that point.

the solid forms at .....

explanation .....

.....

[3]

(iv) The experiment was repeated at a higher temperature.

Predict how the results of the experiment would be different. Explain your answer.

.....

.....

..... [3]

(b) Some of the white solid is removed from the tube and dissolved in water.

Describe how the white solid could be tested to show it contains,

(i) ammonium ions,

test .....

.....

result .....

.....

[3]

(ii) chloride ions.

test .....

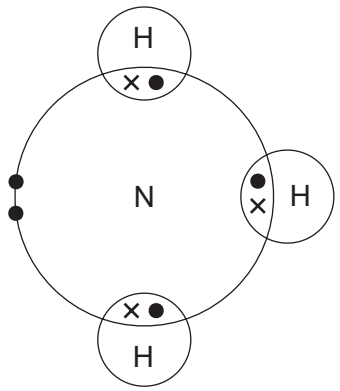
.....

result .....

.....

[3]

(c) The diagram shows the electron arrangement in a molecule of ammonia, showing only outer shell electrons.

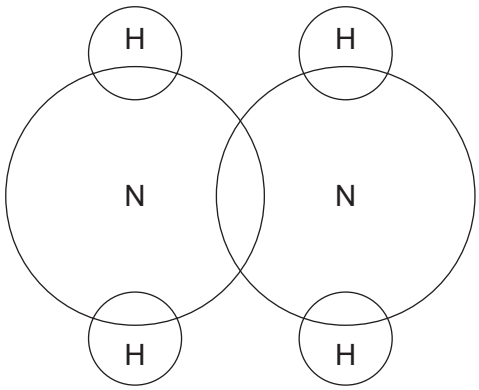


(i) State the type of bonding in ammonia.

..... [1]

(ii) Hydrazine, N_2H_4, is another compound of nitrogen and hydrogen.

Complete the diagram to show the electron arrangement in a molecule of hydrazine, showing only outer shell electrons.



[3]

(d) Nylon and proteins are both polymers containing nitrogen.

(i) Name the linkages found in the polymers of nylon and protein.

..... [1]

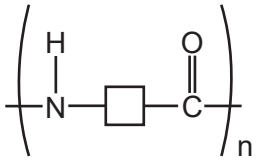
(ii) Describe **one** difference in the structures of nylon and protein.

..... [1]

(iii) What is the general name given to the products of hydrolysis of proteins?

..... [1]

(e) Suggest the structure of the monomer used to make the polymer shown.



[1]

[Total: 22]

4 The table below shows the elements in the third period of the Periodic Table, the number of electrons in their outer energy level, their oxidation state in their common compounds and their melting points.

element	Na	Mg	Al	Si	P	S	Cl	Ar
number of outer electrons	1	2	3	4	5	6	7	8
oxidation state	+1	+2	+3	+4/–4	–3	–2	–1	0
melting point/°C	98	650	660	1414	31	115	–101	–189

(a) Describe and explain the variation in oxidation state across the period.

.....

.....

.....[3]

(b) The first three elements, Na, Mg and Al, are metals.

Describe the structure of a typical metal.

.....

.....

.....

..... [3]

(c) Explain why Na, Mg and Al are good conductors of electricity.

..... [1]

(d) Which element exists as diatomic molecules of the type X_2?

..... [1]

(e) Silicon has a similar structure to diamond.

Explain why silicon has the highest melting point in the period.

.....

..... [2]

(f) Sodium chloride is a crystalline solid with a high melting point. It dissolves in water to give a neutral solution. Phosphorus trichloride is a liquid at room temperature. It reacts with water to form an acidic solution.

Suggest an explanation for these differences in properties.

.....

.....

..... [2]

(g) Describe how you could show that magnesium oxide is a basic oxide and not an amphoteric oxide.

.....

..... [2]

(h) Draw a dot-and-cross diagram showing the bonding in magnesium oxide. Show outer electrons only.

[3]

[Total: 17]