RECOGNISING ACHIEVEMENT

Subject: Foundation Chemistry
Code: 2811

Session: June
Year: 2001

Final Mark Scheme 10/6/2001

MAXIMUM MARK	90

RR 10/6/2001

1. (a) State what is meant by

(i) an *ionic bond*

(electrostatic) attraction between (oppositely charged) ions ✓

[1]

(ii) a *covalent bond*

shared electrons ✓ shared pair ✓

('both shared electrons' scores both marks)

[2]

(b) Draw 'dot-and-cross' diagrams to show the bonding in sodium chloride and hydrogen chloride. You should show outer electron shells only.

NaCl: correct dot and cross ✓

correct charges ✓

HCl: correct dot and cross ✓

[3]

(c) (i) State what is meant by an *orbital*.

a region in which electrons can be found ✓

(Response must imply the 'where the electrons are found'.
Do NOT accept 'path of electron' or 'electron arrangement')

[1]

(ii) Draw diagrams to show the shape of an s orbital and of a p orbital.

s orbital: circle/ellipse ✓

p orbital: figure of eight/'egg-timer' ✓

[2]

(iii) Complete the table below to show how many electrons **completely** fill each of the following

	number of electrons
a p **orbital**	2 ✓
a d **sub shell**	10 ✓
the third **shell**	18 ✓

[3]

[Total: 12]

2. The table below shows the boiling points of the elements sodium to chlorine in Period 3 of the Periodic Table.

element	Na	Mg	Al	Si	P	S	Cl	
bonding	M	M	M	C	C	C	C	✓
structure	G	G	G	G	S	S	S	✓

(a) **(i)** Complete the *'bonding'* row of the table using

- **M** for *metallic bonding*
- **C** for *covalent bonding*

[1]

(ii) Complete the *'structure'* row of the table using

- **S** for a *simple molecular structure*
- **G** for a *giant structure*

[1]

(b) State what is meant by *metallic bonding*. You should draw a diagram as part of your answer.

positive ions/metal ions/cations ✓

surrounded by free/delocalised/sea of electrons ✓

attraction between the above ✓

(Do NOT accept 'holds electrons', 'glue' or 'cement')

[3]

(c) Explain, in terms of their structure and bonding, why the boiling point of

(i) phosphorus is much **lower** than that of silicon,

Si has stronger forces/P has weaker forces ✓ *(i.e. comparison of forces)*

Si: covalent bonds/giant covalent ✓

P: weak forces between molecules/intermolecular forces/van der Waals ✓

[3 ⟶ 2 max]

(ii) aluminium is much **higher** than that of magnesium.

Al has stronger (metallic) bonding ✓

(If 'stronger covalent forces' then WRONG)

Al has 3 outer electrons, Mg has 2/Al has more (outer) electrons than Mg ✓

Al ions are smaller/ more positive/Al ions have a greater charge density ✓

[3 ⟶ 2 max]

[Total: 9]

3. Hydrogen chloride, HCl, is a colourless gas which dissolves very readily in water forming hydrochloric acid.

(a) At room temperature and pressure, 1.00 dm^3 of water dissolves 432 dm^3 of hydrogen chloride gas.

(i) How many moles of hydrogen chloride dissolve in the water?

432/24 = 18 mol ✓

[1]

(ii) The hydrochloric acid formed has a volume of 1.40 dm^3. What is the concentration, in mol dm^{-3}, of the hydrochloric acid?

18/1.4 = 12.9 mol dm^{-3} ✓ *(Look for 12.86) i.e. ans to (a)(i) / 1.4)*

[1]

(b) In solution, the molecules of hydrogen chloride ionise:

$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$

Describe a simple test to confirm the presence of chloride ions.

Add $AgNO_3(aq)$ ✓

white (precipitate) ✓

Alternative: "electrolysis giving chlorine ✓ which bleaches indicator paper ✓"

[2]

(c) Hydrochloric acid reacts with magnesium oxide, MgO, and magnesium carbonate, $MgCO_3$.

For each reaction, state what you would expect to see and write a balanced equation.

(i) MgO dissolves/disappears ✓

$MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$ ✓ (state symbols not required)

[2]

(ii) $MgCO_3$ bubbles/fizzing/CO_2 evolved or formed ✓

$MgCO_3(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ ✓

(state symbols not required)

[2]

[Total: 8]

4. Sulphur and sulphur compounds are common in the environment.

(a) A sample of sulphur from a volcano contained 88% by mass of ^{32}S and 12% by mass of ^{34}S.

(i) Complete the table below to show the atomic structure of these isotopes of sulphur.

isotope	number of		
	protons	neutrons	electrons
^{32}S	16	16	16 ✓
^{34}S	16	18	16 ✓

[2]

(ii) Define the term *relative atomic mass*.

average **atomic** mass/weighted mean/average mass

(MUST include reference to atoms or isotopes) ✓

compared with carbon-12 ✓

1/12th of mass of carbon-12/on a scale where carbon-12 is 12 ✓

[3]

(iii) Calculate the relative atomic mass of the volcanic sulphur. Your answer should be given to three significant figures.

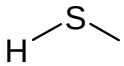
88*32/100 + 12*34/100 ✓

= 32.2 ✓ *(to 3 sig figs: allow full marks for answer. 32.24 (calc) gets 1 mark only)*

[2]

(b) Rotten eggs smell of hydrogen sulphide H_2S, which is a poisonous gas.

Draw a diagram to show the likely shape and bond angle of a hydrogen sulphide molecule. Explain how you have made your choice.



✓ 104 - 105° ✓ *(accept 91-105°)*

Watch for bond angle between S–H and lone pair: this is WRONG)

electron pair repulsion / 4 electron pairs ✓

[3]

(c) Calculate the empirical formula of DMS.

mole ratio: $\frac{38.6}{12}$ C : $\frac{9.7}{1}$ H : $\frac{51.7}{32.1}$ S ✓

i.e. correct use of '12', '1' and 32.1.

= 2 : 6 : 1 / empirical formula = C_2H_6S ✓

(If 16 is used for S, then emp formula $\longrightarrow$ *CH_3S.*

OR C: 6 and S: 16, $\longrightarrow$ C_2H_3S *Worth 1 mark)*

[2]

[Total: 12]

5. The reaction between barium and water is a redox reaction.

$$Ba(s) + 2H_2O(l) \longrightarrow Ba(OH)_2(aq) + H_2(g)$$

(a) Explain, in terms of electrons, what is meant by

(i) oxidation

loss (of electrons) ✓

[1]

(ii) reduction

gain (of electrons) ✓

[1]

(b) Which element has been oxidised in this reaction. Deduce the change in its oxidation state.

Ba ✓

0 to +2 (needs to be completely correct) ✓

[2]

(c) A student reacted 2.74g of barium with water to form 250 cm^3 of aqueous barium hydroxide.

(i) Calculate how many moles of Ba reacted.

2.74/137 / 0.0200 mol ✓

[1]

(ii) Calculate the concentration, in mol dm^{-3}, of $Ba(OH)_2$ was formed.

ans to (c)(i) x 4 mol dm^{-3} ✓ correct answer: 0.0800 mol dm^{-3}

[1]

(iii) Calculate the volume of H_2 that would be produced at room temperature and pressure (r.t.p.). [1 mol of gas molecules occupies 24.0 dm^3 at r.t.p.]

ans to (c)(i) x 24.0 dm^3 ✓ correct answer: 0.480 dm^3 / 480 cm^3

[1]

(iv) The solution of barium hydroxide is alkaline. Identify a compound that could be added to neutralise this solution and write a balanced equation for the reaction that would take place.

any acid ✓

balanced equation to match acid chosen ✓

[2]

(d) The Group 2 elements react more vigorously with water as the group is descended. This can be explained in part by using ionisation energies.

(i) Define the term *first ionisation energy*.

Energy change when **each atom in 1 mole** ✓

of **gaseous atoms** ✓

loses an electron ✓ (to form 1 mole of gaseous 1+ ions).

(or 1 mole of gaseous atoms loses 1 mole of electrons)

[3]

(ii) Explain, in terms of ionisation energies, why the Group 2 elements become more reactive as the group is descended.

ionisation energy decreases ✓

electron is further from nucleus/ electron in a different shell ✓

electron experiences **more** shielding ✓

*(Watch out for **comparison: 'shielding' alone is not enough for mark)***

nuclear attraction decreases/distance or shielding outweighs nuclear attraction/

electron is easier to lose/effective nuclear charge decreases ✓

[4]

[Total: 16]

6. The boiling points of water, hydrogen chloride and argon are shown in Table 7.1 below.

substance	H_2O	HCl	Ar
boiling point /°C	100	–85	–186
number of electrons per molecule	10	18	18

(a) H_2O, HCl and Ar all have van der Waals' forces.

Outline how van der Waals' forces arise between molecules.

oscillating/changing/temporary/transient dipole on one atom ✓

causes an induced/resultant dipole on another molecule/atom ✓

[2]

(b) Liquid H_2O has additional intermolecular forces.

(i) What are these forces?

H_2O: Hydrogen bonds ✓

[1]

(ii) Explain, with the aid of a diagram, how these forces arise between molecules of $H_2O(l)$.

electronegativity/polarity: O **more** electronegative than H

/O is very electronegative ✓

H_2O have polar molecules ✓ *(could be from diagram)*

H bonding: dipoles in water **correctly** shown ✓

H-bond between H and an O in another H_2O molecule ✓

Involvement of lone pair on oxygen ✓

[5]

(c) Liquid HCl also has additional intermolecular forces. What are these forces?

permanent dipole-dipole interactions ✓

[1]

(d) Explain the variation in boiling points shown in Table 7.1.

H-bonds are the strongest ✓

van der Waals' forces/ forces between Ar atoms are the weakest ✓

(i.e. responses should confirm order of strength of 3 types of forces)

[2]

[Total: 11]

7. The bones in an adult human skeleton have a mass of approximately 9 kg. Of this, 1 kg is calcium.

(a) The calcium in bones is present as calcium ions, Ca^{2+}.

Complete the electronic configurations of the following.

a calcium atom: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ ✓

a calcium ion: $1s^2 2s^2 2p^6 3s^2 3p^6$ ✓

[2]

(b) Calculate the approximate number of calcium ions in an adult human skeleton.

moles of Ca = 1000/40.1 = approx 25 ✓

(IF atomic number is used for Ca (20), then 1st mark is lost but 2nd mark gained)

number of calcium ions = $6 \times 10^{23} \times 25 = 1.5 \times 10^{25}$ ✓

[2]

(c) Explain why calcium atoms are **not** present in a human skeleton?

Ca^{2+} ions more stable than Ca/

Ca atoms react with water/too reactive ✓

[1]

(d) The calcium in bones can be assumed to be present as calcium phosphate. A phosphate ion has the formula PO_4^{3-}.

(i) What is the formula of calcium phosphate?

$Ca_3(PO_4)_2$ ✓

[1]

(ii) Estimate the percentage, by mass, of calcium phosphate in an adult human skeleton.

$Ca_3(PO_4)_2$ has a molar mass of $(40.1 \times 3) + (31 + 16 \times 4)2 = 310.3$ g mol^{-1} ✓

mass of $Ca_3(PO_4)_2$ in bone = 310.3/120.3 = 2.58 kg ✓

% of $Ca_3(PO_4)_2$ in bone = $(2.58/9) \times 100 = 29\%$ ✓ (28.6%)

(i.e. 1 mark for molar mass of ans to (d)(i).

1 mark for multiplying by 100/9

1 mark for proportion idea i.e dividing by 120.3)

$CaPO_4$ gives M_r of 135.1/135.

[3]

[Total: 9]

8. Compare and explain the electrical conductivity of sodium chloride, diamond and graphite. In your answer, you should consider the structure and bonding of each of these materials.

In this question, 2 marks are available for the quality of written communication.

NaCl: giant ✓ ionic ✓ lattice

fixed ions in solid ✓

does not conduct when solid ✓

does conduct when aqueous/ molten ✓

mobile ions in solution or when molten ✓

6 marks max 5

Diamond **OR** graphite:

covalent ✓ giant ✓

Diamond: no free electrons/ions/charge carriers/all electrons involved in bonding ✓

does not conduct at all *(NOT poor conductor)* ✓

Graphite: layered structure ✓

delocalised electrons (between layers) ✓

conducts (by movement of delocalised electrons) ✓

7 marks max 6

Q – legible text with accurate spelling, punctuation and grammar ✓

Clear, well-organised, using specialist terms 5 or more ✓

[Total: 13]