Subject: Chemistry Foundation
Code: 2811

Session: January
Year: 2001

Final Mark Scheme

14th Jan 2001

MAXIMUM MARK	90

Answer **all** questions

1. Lithium was discovered in 1817 by the Swedish chemist Arfvedson. Lithium exists naturally as a mixture of isotopes.

(a) Explain the term *isotopes*.

Atoms of the same element with different masses/

Same atomic number, different number of neutrons/

Atoms of the same element with different numbers of neutrons ✓

Response must imply atoms [1]

(b) Which isotope is used as the standard against which relative atomic masses are measured?

carbon-12 ✓

[1]

(c) The mass spectrum below shows the isotopes present in a sample of lithium:

(i) Use this mass spectrum to help you complete the table below for each lithium isotope in the sample.

isotope	percentage composition	number of protons	number of neutrons
^{6}Li	9 to 6	3	3
^{7}Li	91 to 94	3	4
mark	must add up to 100 ✓	✓	✓

For last 2, mark by column or row

[3]

(ii) Calculate the relative atomic mass of this lithium sample. Your answer should be given to three significant figures.

8 x 6/100 + 92 x 7/100 ✓ = 6.92 ✓ *(91/9 → 6.91; 93/7 → 6.93; 94/6 → 6.94)*

[2]

(d) The species responsible for the peaks in this mass spectrum are lithium ions, produced and separated in a mass spectrometer.

(i) How are the electrons removed from lithium atoms to form lithium ions in a mass spectrometer?

(bombarded) with electrons ✓

[1]

(ii) How does a mass spectrometer separate the ions?

(deflected by) a magnet(ic field) ✓

[1]

(e) The first ionisation energy of lithium is +520 kJ mol^{-1}.

(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).

[3]

(ii) The first ionisation energy of sodium is +496 kJ mol^{-1}.

Explain why the first ionisation energy of sodium is less than that of lithium. Your answer should compare the atomic structures of each element.

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

electron experiences more shielding ✓

nuclear attraction decreases/distance or shielding outweighs nuclear attraction/ effective nuclear charge is less ✓

[3]

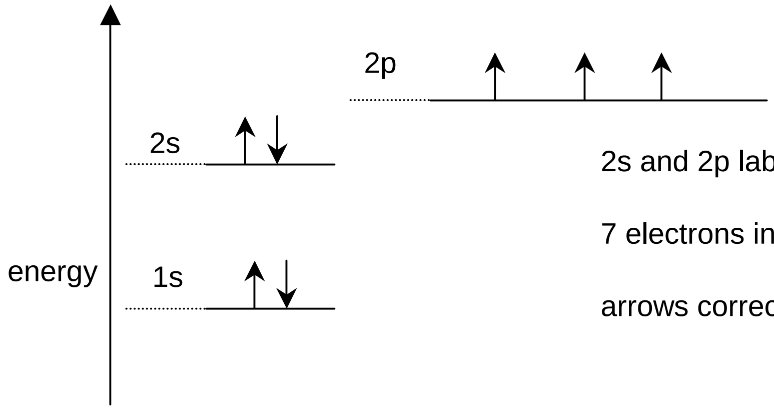
[Total: 15]

2. Electrons are arranged in energy levels. The diagram below is incomplete. It shows two electrons in the 1s level.

(a) Complete the diagram for the 7 electrons in a nitrogen atom by

(i) adding labels for the other sub-shell levels, [1]

(ii) showing how the electrons are arranged. [2]



2s and 2p labels ✓

7 electrons in correct levels ✓

arrows correctly shown ✓

[3]

(b) Magnesium reacts with nitrogen forming magnesium nitride, which is an ionic compound.

(i) Complete the electronic configuration for the 12 electrons in a magnesium atom.

$1s^2 2s^2 2p^6 3s^2$ ✓ [1]

(ii) What is the charge on each ion in magnesium nitride?

magnesium ion 2+ ✓

nitride ion 3– ✓

[2]

(iii) Complete the electronic configuration of each **ion** in magnesium nitride.

magnesium ion $1s^2 2s^2 2p^6$ ✓

nitride ion $1s^2 2s^2 2p^6$ ✓

[2]

(iv) Deduce the formula of magnesium nitride.

Mg_3N_2 ✓

[1]

(c) Magnesium reacts with carbon dioxide forming a mixture of magnesium oxide and carbon.

(i) Write an equation, with state symbols, for this reaction.

$2Mg(s) + CO_2(g) \longrightarrow 2MgO(s) + C(s)$ equation: ✓ state symbols: ✓ [2]

(ii) When water is added to the mixture containing magnesium oxide, some of the magnesium oxide reacts to form a solution of magnesium hydroxide.

$MgO(s) + H_2O(l) \longrightarrow Mg(OH)_2(aq)$

Predict the pH of this solution. 8 – 12 ✓ [1]

[Total: 12]

3. Calcium carbonate is added to an excess of hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) Deduce **two** observations that you would expect to see during this reaction.

observation 1

$CaCO_3$ dissolves/ $CaCO_3$ disappears/ a solution forms ✓

observation 2

fizzing/effervescence/gas evolved/CO_2 evolved ✓

[2]

(b) In this experiment, 0.04 g $CaCO_3$ is added to 25 cm^3 of 0.05 mol dm^{-3} HCl.

(i) Explain what is meant by 0.05 mol dm^{-3} HCl.

0.050 mol/1.825 g HCl (is dissolved) in 1 dm^3 ✓

of solution ✓

[2]

(ii) Calculate how many moles of $CaCO_3$ were used in this experiment.

molar mass of $CaCO_3$ 100 g mol^{-1} ✓

moles of $CaCO_3$ = 0.040/100.1 = 0.00040 ✓ *(calc value: 3.996; accept $CaCO_3$:100)*

[2]

(iii) Calculate how many moles of HCl are required to react with this amount of $CaCO_3$.

moles of HCl that react = 2 x 0.00040 = 0.00080 ✓ *(i.e. ans to (b)(ii) x 2)*

[1]

(iv) Hence show that the HCl is in excess.

moles of HCl used = 0.050 x 25/1000 = 0.00125 ✓ *(accept: 16 cm^3 HCl used)*

[1]

(c) State **one** large-scale use of a named Group 2 compound that is being used to reduce acidity.

NAMED material + example of neutralising for mark. Can be common name:

e.g. Milk of magnesia/MgO for combating acid indigestion

limestone/$CaCO_3$ (or lime/CaO/$Ca(OH)_2$ for combating acidity in fields ✓

Material must be a Group 2 carbonate/oxide/hydroxide [1]

[Total: 9]

4. Water is the most abundant compound on Earth. Much of the chemistry of water is influenced by its polarity and ability to form hydrogen bonds.

(a) Polarity can be explained in terms of electronegativity.

(i) Explain the term *electronegativity*.

attraction (of an atoms) for electrons ✓

in a (covalent) bond ✓

[2]

(ii) Why are water molecules polar?

O and H have different electronegativities / O attracts electrons more than H/

O is very electronegative ✓

[1]

(b) The polarity of water molecules results in the formation of hydrogen bonds.

(i) Draw a diagram to show hydrogen bonding between two molecules of water.

Your diagram must include dipoles and lone pairs of electrons.

non-linear H_2O molecule ✓

dipoles in water shown ✓

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

Involvement of lone pair on oxygen✓

Linear H----O–H ✓

(HO_2 can score dipole mark only) [4]

(ii) State the bond angle in a water molecule

bond angle = 104.5 ° ✓ (*accept 104-105 °)*

[1]

(c) State and explain **two** properties of **ice** that are a direct result of hydrogen bonding.

property high(er) melting/boiling point (than expected) ✓

explanation strength of H bonds/H-bonds need to be broken/H-bonds strong ✓

property ice is lighter than water/ max density at 4°C/ice floats ✓

explanation H bonds hold H_2O molecules apart/open lattice in ice/ H-bond is long ✓

(*Final mark must imply space within structure;*
do NOT accept 'air trapped')

[4]

[Total: 12]

5. Well over 2 000 000 tonnes of sulphuric acid, H_2SO_4, are produced in the U.K. each year. This is used in the manufacture of many important materials such as paints, fertilizers, detergents, plastics, dyestuffs and fibres.

(a) 100 tonnes of sulphur dioxide were reacted with oxygen in stage 2.

Assuming that the reaction was complete, calculate

(i) how many moles of sulphur dioxide were reacted;

M_r: SO_2, 64.1. 1 tonne = 1 x 10^6 g

moles SO_2 = 100 x 10^6/64.1 = 1.56 x 10^6 ✓

[1]

(ii) the mass of sulphur trioxide that formed.

M_r: SO_3, 80.1

mass SO_2 = 1.56 x 10^6 x 80.1 = 125 x 10^6 g / 125 tonne ✓

[1]

(b) Construct a balanced equation for the formation of sulphuric acid from oleum.

$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$ ✓

[1]

(c) The concentration of the sulphuric acid can be checked by titration. A sample of the sulphuric acid was analysed as follows.

- 10.0 cm^3 of sulphuric acid was diluted with water to make 1.00 dm^3 of solution.
- The diluted sulphuric acid was then titrated with aqueous sodium hydroxide, NaOH.

  $H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$
- In the titration, 25.0 cm^3 of 0.100 mol dm^{-3} aqueous sodium hydroxide required 20.0 cm^3 of **diluted** sulphuric acid for neutralisation.

(i) Calculate how many moles of NaOH were used.

0.100 x 25/1000 = 2.5 x 10^{-3} mol ✓

[1]

(ii) Calculate the concentration, in mol dm^{-3}, of the **diluted** sulphuric acid, H_2SO_4.

moles H_2SO_4 = 1.25 x 10^{-3} ✓

concentration H_2SO_4 = 1.25 x 10^{-3} x 1000/20 = 0.0625 mol dm^{-3} ✓

(*i.e. Ans to (c)(i) x ½) An answer of 0.125 mol dm*$^{-3}$ *would score probably 2nd mark- error likely to be molar ratio in equation)* [2]

(iii) Calculate the concentration, in mol dm^{-3}, of the original sulphuric acid submitted for analysis.

100 x 0.0625 = 6.25 mol dm^{-3} ✓

(*i.e. Ans to (c)(ii) x 100)* [1]

[Total: 7]

6. The atomic radii of the elements Li to F and Na to Cl are shown in the table below.

element	Li	Be	B	C	N	O	F
atomic radius/nm	0.134	0.125	0.090	0.077	0.075	0.073	0.071
element	Na	Mg	Al	Si	P	S	Cl
atomic radius/nm	0.154	0.145	0.130	0.118	0.110	0.102	0.099

(a) Using **only** the elements in this table, select

(i) an element with **both** metallic and non-metallic properties,

Si/C/B ✓

[1]

(ii) the element with the largest first ionisation energy

F ✓

[1]

(iii) an element with a giant covalent structure

Si/C/B ✓

[1]

(b) Explain what causes the general **decrease** in atomic radii across each period?

electrons added to same shell /same or similar shielding ✓

increasing nuclear charge/number of protons ✓

electrons experience greater attraction ✓

[3]

(c) Predict and explain whether the size of a sodium **ion** is *larger* or *smaller* than the size of a sodium **atom**.

sodium ion is smaller ✓

shell has been lost ✓

same protons attracting fewer electrons/less electron shielding/

effective nuclear charge greater ✓

(*If 'Na ion is larger' and all else is correct then penalise 1st mark only)*

[3]

[Total: 9]

7. Chlorine and its compounds have many uses. Chlorine bleach is used to kill bacteria.

(a) Chlorine bleach is made by the reaction of chlorine with aqueous sodium hydroxide.

$Cl_2(g) + NaOH(aq) \longrightarrow NaOCl(aq) + NaCl(aq) + H_2O(l)$

(i) Determine the oxidation number of chlorine in

Cl_2 0 ✓ NaClO +1 ✓ NaCl –1 ✓

[3]

(ii) The actual bleaching agent is the ClO^- ion. In the presence of sunlight, this ion decomposes to release oxygen gas.

Construct an equation for this reaction.

$2ClO^- \longrightarrow 2Cl^- + O_2$ or $2NaClO \longrightarrow 2NaCl + O_2$ ✓

[1]

(b) The sea contains a low concentration of bromide ions. Bromine can be extracted from sea water by first concentrating the sea water and then bubbling chlorine through this solution.

(i) The chlorine oxidises bromide ions to bromine.

Construct a balanced ionic equation for this reaction

$Cl_2 + 2Br^- \longrightarrow Br_2 + 2Cl^-$ ✓

[1]

(ii) Suggest how bromine could be removed from the seawater after the extraction with chlorine.

distill/blow air through/evaporate/use organic solvent ✓

('Evaporate water' is wrong although 'evaporate' is correct: implies Br_2)

'Heat' is wrong

[1]

(c) Phosgene is a compound of chlorine, carbon and oxygen, used to make polyurethanes and dyes.

Phosgene has the percentage composition by mass: Cl, 71.7%; C, 12.1%; O, 16.2%.

(i) Show that the empirical formula of phosgene is Cl_2CO.

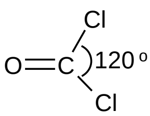
mole ratio: $\frac{71.7}{35.5}$ Cl : $\frac{16.2}{16}$ O : $\frac{12.1}{12}$ C ✓ *i.e. correct use of '35.5', '16' and 12.*

= 2 : 1 : 1 OR 2.02:1.01:2.02 ✓

[2]

(ii) The molecular formula of phosgene is the same as its empirical formula.

Draw a possible structure, including bond angles, for a molecule of phosgene.



shape (*C=O IS required)* ✓ ; bond angle (accept 115 - 125°) ✓

[2]

[Total: 10]

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

Sodium reacts with chlorine forming sodium chloride.

(a) Describe the bonding in Na, Cl_2 and NaCl. [8]

Na, Cl_2 and *NaCl*: metallic, covalent and ionic bonding respectively ✓.

NaCl: (ionic bonding): electrostatic attraction between ions ✓

correct 'dot-and-cross' diagram ✓

correct charges shown ✓

Cl_2: (covalent bonding): attraction of shared electrons for 2 nuclei ✓

'dot-and-cross' diagram correct ✓

shared pair of electrons ✓

(*'shared' electrons must be described but 'pair' can be within dot-and-cross diagram*)

'dot-and-cross' diagram correct ✓

Na: (metallic bonding): attraction between ions and electrons ✓

delocalised electrons ✓

(*marks could be obtained by suitably annotated diagram*)

Clear, well-organised, using specialist terms

More than half marks likely to score this mark but some writing is essential

Show mark as: Q ✓

[Sub-total: 10 $\longrightarrow$ 8 max]

(b) Relate the **physical** properties of Cl_2 and NaCl to their structure and bonding. [8]

For Cl_2 and for NaCl, mark **best two properties** only (treat as 3 x 2 'pairs').

Cl_2: *choose best two props.*

- poor conductor of electricity ✓ : no mobile electrons or ions ✓
- low m/bt pt: weak intermolecular ✓ van der Waals' forces/simple molecular structure ✓
- soluble in non-polar solvents ✓ : which interact with Cl_2 ✓ $\longrightarrow$ 4 max

NaCl: *choose best two props.*

- conducts only when aq or liquid ✓ when ions are mobile/ ions fixed in lattice ✓
- high m/bt pt ✓ : strong forces between ions/giant ionic lattice ✓
- soluble in polar solvents ✓ : dipoles interact with ions ✓ $\longrightarrow$ 4 max

Q – legible text with accurate spelling, punctuation and grammar

More than half marks likely to score this mark but do pay attention to SPG

Show mark as: Q ✓

[Sub-total: 9 $\longrightarrow$ 8 max]

[Total: 16]