WJEC EDUQAS A-LEVEL CHEMISTRY · COMPONENT 1

CHEMISTRY



EXAM QUESTION PACK

PI2.1 CHEMISTRY OF THE P-BLOCK

SCORE	PERCENTAGE
/81	%

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1. Name an element that has a half-filled set of *p*-orbitals.

[1]

(Total 1)

2. Sketch the shape of **one** *p*-orbital.

[1]

(Total 1)

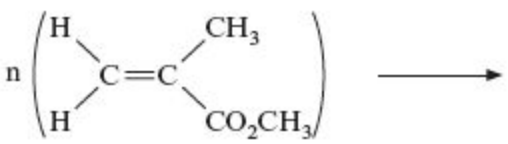
3. Boron, B, has the atomic number 5 and it forms a fluoride, BF_3.

(a) BF_3 is used to initiate certain types of addition polymerisation of unsaturated compounds.

(i) Ethene is an example of an unsaturated compound. Describe the bonding between the carbon atoms in ethene. You may wish to draw a labelled diagram. [2]

(ii) State what is meant by *polymerisation*. [1]

(iii) A colourless plastic used to cover lights is made from methyl methacrylate by a process similar to the polymerisation of ethene. Complete the equation by giving the formula of the repeating unit. [1]



(iv) Addition polymerisation is used to make synthetic rubber. The molecular formula of the monomer used is C_4H_5Cl. What is the **empirical** formula of the synthetic rubber polymer? [1]

.....

(b) (i) Use the VSEPR theory to deduce the shapes of BF_3 and NH_3. [2]

Shape of BF_3 .....

Shape of NH_3 .....

(ii) Explain the difference in the shapes of BF_3 and NH_3. [2]
QWC [1]

.....

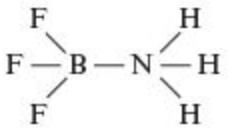
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(c) Boron fluoride reacts with ammonia, NH_3, to make the compound shown in the following equation.

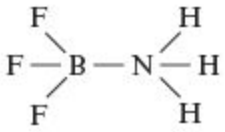
$$BF_3 + NH_3 \longrightarrow$$



(i) Name the type of bond formed between N and B. [1]

.....

(ii) Suggest a value for the F–B–F bond angle in this molecule.



Bond angle ..... [1]

(iii) Explain your answer to part (ii). [1]

.....

.....

Total [13]

4.

Read the passage below and then answer the questions in the spaces provided.

The Chemistry of Boron

Boron is an element at the top of Group 3. It forms a range of compounds whose behaviour is very different from the other elements in the same group. Boron shows the properties of a non-metal, however the remaining elements, including aluminium, gallium, indium and thallium all show metallic properties. This change is similar to that seen in other groups in the p-block with Group 4 having the non-metal carbon at the top and the metal lead at the bottom. In its compounds, boron exhibits the +3 oxidation state exclusively, forming materials such as BCl_3, BF_3 and B_2O_3. No compounds with a +1 oxidation state are known. Aluminium also exists only as the +3 oxidation state, however the +1 oxidation state becomes more common as the group is descended.

Boranes

There are very many compounds formed between boron and hydrogen and these are called boranes. These boranes are grouped into series and two examples of these are:

- *Nido*-boranes with a general formula of B_nH_{n+4}. This series includes pentaborane(9), B_5H_9, and decaborane(14), $B_{10}H_{14}$.
- *Arachno*-boranes with a general formula of B_nH_{n+6}. The first member of this series is tetraborane(10), B_4H_{10}.

All of these boranes are electron deficient, which leads them to be very reactive. The majority react explosively on contact with air, which led to their proposed use as a rocket fuel. To destroy the stockpile of B_5H_9 when it was no longer needed, the US government treated it with steam to form a solution of boric acid (H_3BO_3) and hydrogen gas.

Boron nitride

Boron nitride has a giant covalent structure that has the same number of electrons as graphite and diamond. They are said to be isoelectronic. Boron nitride exists in two forms:

- Hexagonal boron nitride has a structure similar to graphite, and is sometimes called 'white graphite' because of its excellent lubricating properties. Unlike graphite, hexagonal boron nitride is an insulator and has applications which depend upon this property.
- Cubic boron nitride has a diamond structure, and is the second hardest natural material known. It has high thermal conductivity and is chemically inert.

Uses of boron compounds

Nearly all boron ore extracted from the Earth is destined for refinement into boric acid and sodium tetraborate. Most boric acid is used in the production of shock-resistant glass, whilst sodium tetraborate is used as an additive to detergents. Boron is also used in nuclear reactors, where boron shielding is used as a control, taking advantage of its high cross-section for neutron capture.

- End of passage -

(a) Explain why boron forms compounds with the +3 oxidation state alone, but thallium compounds are more stable with the +1 oxidation state *(lines 6-9).*

[2]

(b) Boranes are compounds made up of boron and hydrogen only *(lines 11-16)*. A sample of a gaseous borane was found to contain 78.14 % boron and 21.86 % hydrogen by mass. A sample of this borane of mass 1.232 g occupied a volume of 1 dm3 at 273 K and 1 atm pressure.

[The molar volume of a gas at 273 K and 1 atm pressure is 22.4 dm^3.]

(i) What is the empirical formula of this borane?

[2]

Empirical formula .....

(ii) What is the molecular formula of this borane?

[3]

Molecular formula .....

(c) Explain the term *electron deficient (line 17)*.

[1]

(d) Balance the equation for the reaction of pentaborane(9), B_5H_9, with steam *(lines 18-20)*. [1]

..... B_5H_9 + ... H_2O ⟶ ..... H_3BO_3 + ... H_2

(e) The standard enthalpy change of formation of pentaborane(9) is +42.8 kJ mol^{-1}. State what information this value gives about the stability of this compound. [1]

(f) Hexagonal boron nitride and graphite have similar structures *(lines 24-26)*. Describe the differences between these two isoelectronic materials in terms of their bonding and structure.

[3] QWC [1]

(g) Boron-10 absorbs a neutron *(line 33)* to form an intermediate, which then decays by emission of an alpha particle.

Give the mass number and atomic number of the final product.

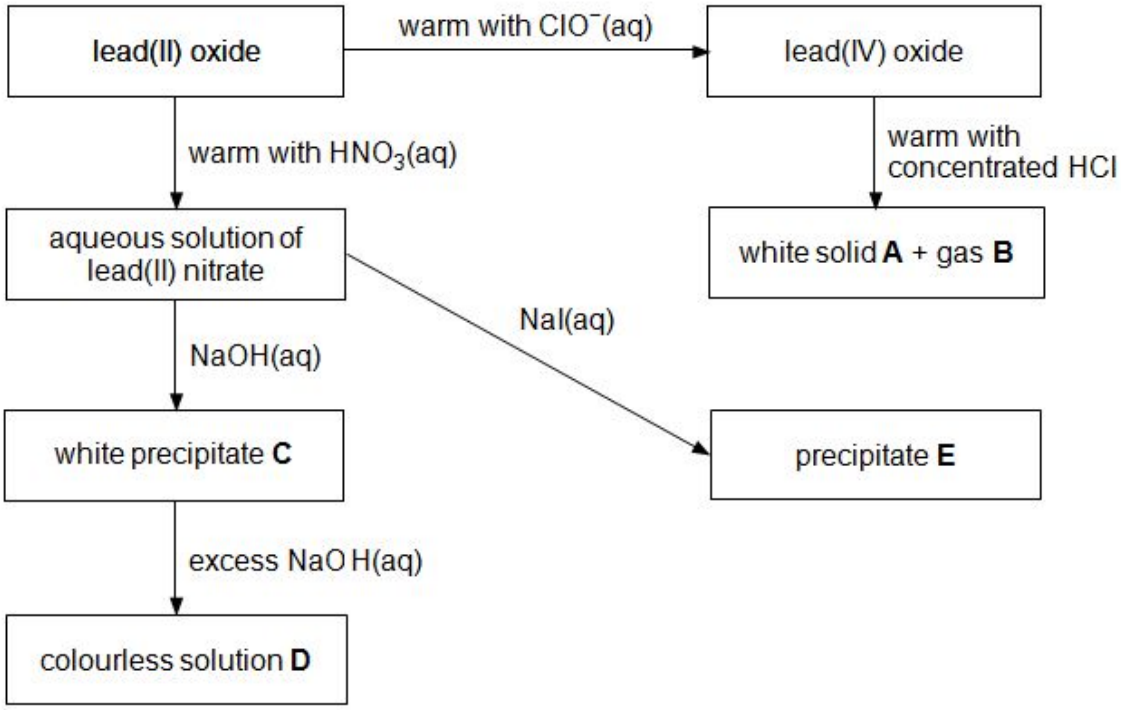
[1]

Mass number.....

Atomic number.....

(Total 15)

5. *(a)* The diagram shows some of the reactions of lead compounds.



(i) State the role of lead(IV) oxide in the reaction with concentrated hydrochloric acid.

[1]

(ii) Name white solid **A** and gas **B**.

[2]

(iii) Give the formula of the lead-containing species present in colourless solution **D**.

[1]

(iv) Give the colour of precipitate **E**.

[1]

(v) Write the equation for the formation of lead(II) nitrate from lead(II) oxide.

[1]

(b) Carbon is the first element in Group 4. Two of its allotropes are diamond and graphite. A compound that forms structures corresponding to diamond and graphite is boron nitride.

(i) Describe the structure of graphite and explain why **hexagonal** boron nitride can adopt the same structure yet have different electrical conductivity properties.

[4] QWC [1]

(ii) State **one** use for the **cubic** boron nitride structure.

[1]

(c) Another element in Group 4 is tin. At low temperatures tin exists as its grey form. At higher temperatures the white form is stable. The change can be represented by the equation:

$$Sn_{(grey)} \longrightarrow Sn_{(white)} \qquad \Delta H^{\ominus} = 1.92\,kJ\,mol^{-1}$$

The standard entropy values are $44.8\,J\,K^{-1}\,mol^{-1}$ for grey tin and $51.5\,J\,K^{-1}\,mol^{-1}$ for white tin.

(i) Calculate the minimum temperature needed to cause grey tin to change to white tin.

[3]

(ii) During Napoleon's disastrous campaign in Russia from June to December in 1812 the tin buttons on his infantry's uniforms disintegrated. Suggest a reason why this might have happened.

[1]

(d)An important technological development in recent years has been the hydrogen fuel cell. This uses electrochemical methods to get energy from hydrogen.

(i) Write the half-equations for the processes occurring at the electrodes and an equation for the overall reaction.

[3]

(ii) Give **one** disadvantage of using hydrogen fuel cells to power vehicles.

[1]

(Total 20)

6. This question is about atomic structure.

(a) Give the full electronic configuration of a nitrogen atom and use this to describe the way in which electrons are arranged in atoms.

[4] QWC [1]

(b) Describe the main features of the atomic emission spectrum of hydrogen in the visible region. Explain how these features arise and how their interpretation provides evidence for energy levels in the atom.

[6]

(c)(i) Hydrogen has a first ionisation energy of 1312 kJ mol^{-1}.Explain why helium has a higher first ionisation energy than hydrogen

[2]

(ii) Beryllium and magnesium are both in Group 2 of the Periodic Table.Explain why beryllium has a higher first ionisation energy than magnesium

[2]

(iii) The table below gives the first three ionisation energies for boron and potassium.

Element	Ionisation energy/kJ mol^{-1}		
	1st	2nd	3rd
B	800	2420	3660
K	419	3051	4412

(I) Suggest why compounds containing B^{3+} ions are unlikely to exist.

[1]

(II) Write an equation to represent the **second** ionisation energy of potassium

[1]

(III) State how the first three ionisation energies of calcium would differ from those of potassium.

[2]

(Total 19)

7. Aluminium, boron and nitrogen all form chlorides containing three chlorine atoms, XCl_3.

(a) Molecules of boron chloride, BCl_3, and molecules of nitrogen chloride, NCl_3, have different shapes.

Use VSEPR (valence shell electron pair repulsion) theory to state and explain the shapes of these molecules. [6]

QWC [2]

(b) The boron atom in boron chloride, BCl_3, is described as being electron deficient. Draw a dot and cross diagram for BCl_3 and use it to show what is meant by the term *electron deficient*. [2]

(c) Nitrogen chloride, NCl_3, is insoluble in cold water whilst the similar compound ammonia, NH_3, is very soluble. Explain this difference in behaviour. [2]

(d) Aluminium chloride, $AlCl_3$, forms a dimer that contains both covalent bonds and coordinate bonds. Describe what is meant by the terms *covalent bond* and *coordinate bond*. [2]

(Total 14)

4 (a) +1 occurs due to inert pair of s-electrons (1)
Inert pair effect becomes more significant down the group (1) [2]

(b) (i)

B	H
78.14	21.86
10.8	1.01
7.235	21.644
1	3

(1)

Empirical formula = BH_3 (1) [2]

(ii) Number of moles = $1/22.4 = 4.46 \times 10^{-2}$ moles (1)

$M_r = 1.232 / 4.46 \times 10^{-2} = 27.6$ (1)

Molecular formula = B_2H_6 (1) [3]

(c) Outer/valence shell of electrons is not full / does not have an octet [1]

(d) $B_5H_9 + 15H_2O \rightarrow 5H_3BO_3 + 12H_2$ [1]

(e) The compound is less stable than the elements [1]

(f) Any 3 from 4 points for (1) each

All atoms the same in graphite / BN alternate in boron nitride (1)
Atoms in layer of BN lie above each other but are not in graphite (1)
B—N bonds are polarised (or indicated dipole) but graphite is non-polar (1)
p-electrons in BN are localised but in graphite are delocalised (1) [3]

QWC *Organisation of information clearly and coherently; use of specialist vocabulary where appropriate* [1]

(g) Mass number = 7 Atomic number =3 [1]

Total [15]

5 (a) (i) Oxidising agent [1]

(ii) A = lead(II) chloride / $PbCl_2$ (1)

B = chlorine / Cl_2 (1) [2]

(iii) $[Pb(OH)_6]^{4-}$ / $[Pb(OH)_4]^{2-}$ / $Na_4[Pb(OH)_6]$ etc. [1]

(iv) Yellow [1]

(v) $PbO + 2HNO_3 \longrightarrow Pb(NO_3)_2 + H_2O$ [1]

(b) (i) Each C atom covalently bonded to three other C atoms forming layers (1)

Layers held together by weak intermolecular forces (1)

BN is isoelectronic with C so it forms similar structures (1)

Graphite conducts electricity since electrons are delocalised but in BN, each N has a full unbonded p-orbital and each B has an empty unbonded p-orbital so it does not conduct electricity (1) [4]

(Accept electrons are not delocalised in BN so it does not conduct electricity)

QWC The information is organised clearly and coherently, using specialist vocabulary where appropriate [1]

(ii) Wear-resistant coatings/catalyst support/for mounting high power electronic components / drills in industry / cutting instruments [1]

(c) (i) $\Delta G = \Delta H - T\,\Delta S$ ($\Delta G = 0$ for reaction to be spontaneous) (1)

$T = \frac{1.92}{0.0067}$ (1)

$T = 286.6$ K (1) [3]

(ii) Changes in temperature (above or below 286.6 K) caused the tin to change form making it unstable (and causing it to disintegrate) [1]

(d) (i) (At the anode) $H_2 \longrightarrow 2H^+ + 2e^-$ (1)

(At the cathode) $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$ (1)

(Overall reaction) $2H_2 + O_2 \longrightarrow 2H_2O$ (1)

[3]

(ii) Hydrogen is difficult to store / takes up large volume / too flammable / explosive / produced from fossil fuels which leads to a net energy loss / Pt electrodes very expensive [1]

Total [20]

6 (a) Electrons within atoms occupy fixed energy levels or shells of increasing energy / nitrogen has electrons in two shells (1)
$1s^2 2s^2 2p^3$ (1)

Electrons occupy atomic orbitals within these shells /
The first shell in nitrogen has s orbitals and the second shell s and p orbitals (1)

A maximum of two electrons can occupy any orbital /
Each s orbital in nitrogen contains two electrons (1)

Each with opposite spins (1)

Orbitals of the same type are grouped together as a sub-shell / There are three p orbitals in nitrogen's p sub-shell (1)

Each orbital in a sub-shell will fill with one electron before pairing starts / In nitrogen's p sub-shell each orbital contains one electron (1)

(configuration mark + any 3 of above) [4]

QWC The information is organised clearly and coherently, using specialist vocabulary where appropriate [1]

(b) Atomic spectrum of hydrogen is a series of lines (1)
that get closer as their frequency increases (1)
(credit possible from labelled diagram)

Lines arise from atom / electrons being excited by absorbing energy (1)
electron jumping up to a higher energy level (1)
falling back down and emitting energy (in the form of electromagnetic radiation) (1)
to the n = 2 level (1)
(any **three** points for maximum 3 marks)

Since lines are discrete energy levels must have fixed values / Since energy emitted is equal to the difference between two energy levels, ΔE is a fixed quantity or quantum (1)

[6]

(c) (i) It has greater nuclear charge (1)
but little / no extra shielding (1) [2]

(ii) In Be less shielding of outer electron (1)
outweighs smaller nuclear charge (1)

or

Be outer electron closer to nucleus (1)
Be has greater effective nuclear charge (1) [2]

(iii) I. Too much energy required to form B^{5+} ion [1]

II. $K^+(g) \rightarrow K^{2+}(g) + e^-$ [1]

III. Value of 1st and 3rd I.E. will be higher (1)
Value of 2nd I.E. will be smaller (1)
(accept large jump in I.E. value would be between 2nd and 3rd electrons for 1 mark) [2]

Total [19]

7 (a)

- BCl_3 is trigonal planar or clear diagram.
- NCl_3 is pyramidal or clear diagram.
- BCl_3 has 3 bonded pairs
- NCl_3 has 3 bonded pairs
- NCl_3 has a lone pair
- BCl_3 has no lone pair
- Electron pairs repel to be as far from each other as possible / position of minimum repulsion.
- Lone pairs repel more than bonded pairs.

First two points and any other 4 for (1) each up to 6 max [6]

- *QWC: selection of a form and style of writing appropriate to purpose and to complexity of subject matter.[1]*
-
- *QWC: legibility of text, accuracy of spelling, punctuation and grammar, clarity of meaning.[1]* [2]

(b)



accept crosses and dots exchanged (1)

Electron deficient: outer shell of boron has less than 8 electrons / is not full.(1) [2]

(c) NH_3 can form hydrogen bonds with water molecules (so it dissolves) (1)
NCl_3 cannot form hydrogen bonding. (1) [2]

(d)

- Covalent has a pair of shared electrons one from each atom (1)
- Coordinate has a pair of shared electrons both electrons from same atom (1)

[2]

Total [14]