

## GCE A LEVEL – CHEMISTRY UNIT 3 QUESTION PACK

1095-01 (Legacy CH5) · New spec Unit 3 Topic 2 · A2 unit, first sat 2017, 80 marks, 1h 45min paper

**REVISE**.wales**CHEMISTRY – UNIT 3 · p-Block Chemistry – Groups 3, 4 & 7**

Topic 3.3 – p-block chemistry: aluminium and Group 3 amphoteric behaviour, Group 4 oxidation states, Group 7 halogens and halides

*Aluminium amphoteric oxide and Group 3 trends; carbon, silicon, germanium, tin and lead +2/+4 oxidation states; tetrachloride hydrolysis; halogen oxidising power, halide reducing power, disproportionation and silver-nitrate halide identification.*

Legacy 2008 specification

**Estimated time for entire question pack: ~2 h 22 min**

*Derived from the legacy CH5 paper's pace of ~1.3 min/mark, padded for long-prose and calculation answers (89 marks over 5 questions).*

*You are advised to **not** attempt to complete all of this in one sitting.*

**ABOUT THIS QUESTION PACK**

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC CH5 papers (2008 modular spec, Jun 2010 – Jun 2016) that maps onto the new-spec A2 Unit 3 Topic 3.3.

Questions are ordered by source paper date.

**INSTRUCTIONS**

Use black ink or black ball-point pen. Show all working – quality of written communication will affect marks. A calculator is allowed. You will need the WJEC Periodic Table / Data Booklet.

*All question content is © WJEC CBAC Ltd. and reproduced for revision purposes.*

For Examiner's use only

Q	Source	Max	Mark
1	Jun 11 Q1	14	
2	Jun 11 Q5	20	
3	Jun 14 Q4	20	

Q	Source	Max	Mark
4	Jun 15 Q3	15	
5	Jun 16 Q5	20	
<b>Total</b>		<b>89</b>	

## p-Block Chemistry – Groups 3, 4 & 7 – what the new spec asks

WJEC GCE A Level Chemistry (from 2015) · Unit 3: Physical & Inorganic Chemistry · Topic 3.3.

### Group 3 – aluminium amphoteric

- $\text{Al}_2\text{O}_3 + \text{acid: } \text{Al}_2\text{O}_3 + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2\text{O}$ .
- $\text{Al}_2\text{O}_3 + \text{alkali: } \text{Al}_2\text{O}_3 + 2\text{OH}^- + 3\text{H}_2\text{O} \rightarrow 2[\text{Al}(\text{OH})_4]^-$ .
- $\text{Al}(\text{OH})_3$  also amphoteric.
- Boron is non-metallic; gallium / indium  $\Rightarrow$  +3 stable.

### Group 4 – C, Si, Ge, Sn, Pb

- Metallic character  $\uparrow$  down group.
- +4 stability  $\downarrow$  down group; +2 stability  $\uparrow$  (inert pair effect).
- C, Si: +4 dominates. Pb: +2 dominates ( $\text{PbO}_2$  is strong oxidiser).
- Sn shows both:  $\text{Sn}^{2+}$  reducing,  $\text{Sn}^{4+}$  stable.

### Tetrachloride hydrolysis

- $\text{CCl}_4$ : *not* hydrolysed – no empty orbital for water lone pair.
- $\text{SiCl}_4$ ,  $\text{GeCl}_4$ ,  $\text{SnCl}_4$ : hydrolyse to give  $\text{MO}_2 + 4\text{HCl}$  (white fumes).
- $\text{PbCl}_4$ : thermally unstable  $\rightarrow \text{PbCl}_2 + \text{Cl}_2$ .

### Group 7 – halogens

- Oxidising power decreases  $\text{F}_2 > \text{Cl}_2 > \text{Br}_2 > \text{I}_2$  (atom  $\uparrow$  size,  $e^-$  shielding  $\uparrow$ ).
- Displacement reactions:  $\text{Cl}_2$  displaces  $\text{Br}^-$  &  $\text{I}^-$ ;  $\text{Br}_2$  displaces  $\text{I}^-$ .
- Halide reducing power:  $\text{I}^- > \text{Br}^- > \text{Cl}^-$ .
- Concentrated  $\text{H}_2\text{SO}_4$ :  $\text{Cl}^- \rightarrow \text{HCl}$ ;  $\text{Br}^- \rightarrow \text{HBr} + \text{Br}_2 + \text{SO}_2$ ;  $\text{I}^- \rightarrow \text{HI} + \text{I}_2 + \text{H}_2\text{S}$ .

### Disproportionation

- $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{HClO}$  (cold water treatment).
- $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$  (cold dilute).
- $3\text{Cl}_2 + 6\text{NaOH} \rightarrow 5\text{NaCl} + \text{NaClO}_3 + 3\text{H}_2\text{O}$  (hot conc.).
- Cl changes from 0 to both -1 and +1 (or +5).

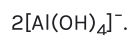
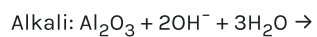
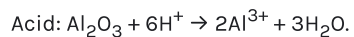
### Halide identification

- $\text{AgNO}_3(\text{aq}) + \text{dilute HNO}_3$ :
- $\text{Cl}^- \rightarrow$  white  $\text{AgCl}$ , dissolves in dilute  $\text{NH}_3$ .
- $\text{Br}^- \rightarrow$  cream  $\text{AgBr}$ , dissolves in conc.  $\text{NH}_3$ .
- $\text{I}^- \rightarrow$  pale yellow  $\text{AgI}$ , insoluble in conc.  $\text{NH}_3$ .

## p-Block Chemistry – Groups 3, 4 & 7 in one page

Quick-reference notes – revisit before each question.

### **Al<sub>2</sub>O<sub>3</sub> amphoteric**



### **Group 4 ox states**

+4 stable: C, Si.

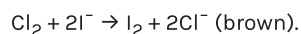
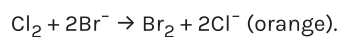
+2 stable: Pb (inert pair).

Sn: both. PbO<sub>2</sub> oxidising; SnCl<sub>2</sub> reducing.

### **Tetrachloride hydrolysis**

$\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$  (vigorous fumes). CCl<sub>4</sub> inert – no empty d-orbital for water attack.

### **Group 7 displacement**



### **Conc. H<sub>2</sub>SO<sub>4</sub> + halides**

Cl<sup>-</sup>: HCl gas only.

Br<sup>-</sup>: HBr + Br<sub>2</sub> + SO<sub>2</sub> (orange fumes).

I<sup>-</sup>: HI + I<sub>2</sub> + S, H<sub>2</sub>S (rotten-egg smell).

### **AgX silver test**

Cl<sup>-</sup> → white AgCl, dissolves dilute NH<sub>3</sub>.

Br<sup>-</sup> → cream AgBr, dissolves conc. NH<sub>3</sub>.

I<sup>-</sup> → pale yellow AgI, insol. conc. NH<sub>3</sub>.

## SECTION A

Answer **all** questions in the spaces provided.

1. Chromium and aluminium both form amphoteric compounds.

(a) State what is meant by the term *amphoteric*.

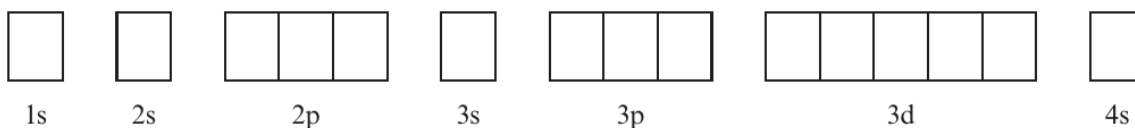
[1]

.....

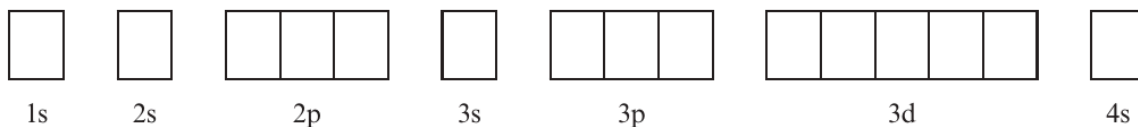
.....

(b) Use arrows in boxes to show the electronic structures of the chromium atom and the  $\text{Cr}^{3+}$  ion. [2]

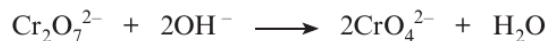
Chromium atom, Cr



Chromium(III) ion,  $\text{Cr}^{3+}$



(c) When sodium hydroxide solution is added to a solution of potassium dichromate(VI),  $\text{K}_2\text{Cr}_2\text{O}_7$ , the following reaction occurs.



(i) State the colour change that is seen.

[1]

.....

(ii) Use the oxidation states of chromium to show that this is not a redox reaction. [2]

.....

.....

Examiner  
only

(d) Aluminium chloride is a compound of the amphoteric element aluminium, whilst magnesium chloride contains the non-amphoteric element magnesium. Explain how sodium hydroxide can be used to distinguish between solutions of these two compounds. [3]

.....

.....

.....

.....

(e) Aluminium chloride,  $\text{AlCl}_3$ , commonly exists as the dimer  $\text{Al}_2\text{Cl}_6$ .

(i) Draw the structure of the dimer formed, and explain why the two  $\text{AlCl}_3$  monomers join together. [3]

.....

.....

.....

.....

(ii) Aluminium chloride monomer may combine with another chloride ion to form tetrachloroaluminate(III) ions,  $\text{AlCl}_4^-$ . Using valence shell electron pair repulsion theory (VSEPR), state and explain the shape of this anion. [2]

.....

.....

.....

.....

Total [14]

5. (a) Give a current use for a named compound of chlorine. [1]
- (b) Chlorine gas,  $\text{Cl}_2$ , is used in the industrial preparation of bromine,  $\text{Br}_2$ . Sea water contains small amounts of bromide ions and by bubbling chlorine gas through the sea water these can be converted to  $\text{Br}_2$ .
- (i) Write an ionic equation for the reaction occurring. [1]
- (ii) Use the standard electrode potentials,  $E^\ominus$ , listed below to explain why chlorine can react with bromide ions but iodine cannot react with bromide ions. [3]

Half-equation	$E^\ominus / \text{V}$
$\text{I}_2 + 2\text{e}^- \rightleftharpoons 2\text{I}^-$	+0.54
$\text{Br}_2 + 2\text{e}^- \rightleftharpoons 2\text{Br}^-$	+1.09
$\text{Cl}_2 + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-$	+1.36

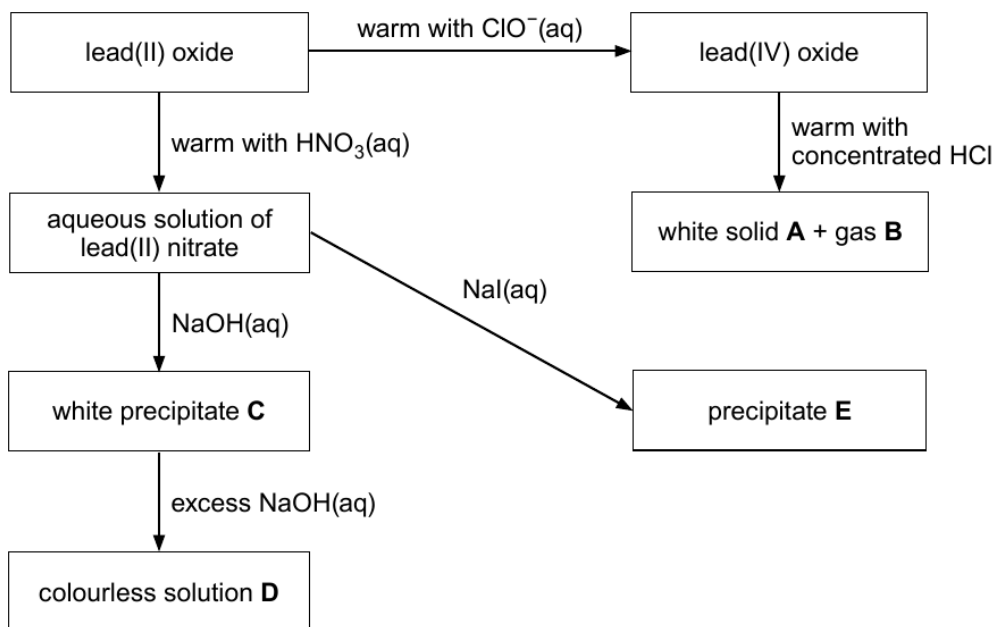
- (c) Sodium chloride and sodium iodide are both compounds which contain halide ions.
- (i) Silver nitrate solution may be used to differentiate between solutions of sodium chloride and sodium iodide. Give the observations that would be expected in **both** cases. [1]
- (ii) Both sodium chloride and sodium iodide react with concentrated sulfuric acid. The observations made during both reactions are very different. Discuss the reactions occurring. Your answer should include
- the observations made during both reactions,
  - the identities of any products,
  - the reasons for any differences in the reactions that occur. [5]
- (QWC) [1]
- (d) Chlorine produces a range of oxoacids, including chloric(I) acid,  $\text{HOCl}$ , and chloric(VII) acid,  $\text{HClO}_4$ . Chloric(I) acid is considered to be a weak acid whilst chloric(VII) acid is considered to be a strong acid.
- (i) What is meant by the term *strong acid*? [1]
- (ii) Write an expression for the acid dissociation constant,  $K_a$ , of chloric(I) acid,  $\text{HOCl}$ . [1]
- (iii) The pH of a solution of chloric(I) acid of concentration  $0.100 \text{ mol dm}^{-3}$  was found to be 4.23. Calculate the concentration of hydrogen ions in this solution. [2]
- (iv) Using the information from part (iii), calculate the value of the acid dissociation constant,  $K_a$ , for chloric(I) acid. [2]
- (v) When the weak acid  $\text{HOCl}$  reacts with the strong base sodium hydroxide it forms the salt sodium chlorate(I),  $\text{NaOCl}$ . Suggest a pH value for a solution of  $\text{NaOCl}$ , giving a reason for your answer. [2]

Total [20]

## SECTION B

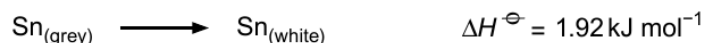
Answer **both** questions in the separate answer book provided.

4. (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:



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

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

### The Chemistry of Boron

5 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  $\text{BCl}_3$ ,  $\text{BF}_3$  and  $\text{B}_2\text{O}_3$ . 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.

#### 10 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  $\text{B}_n\text{H}_{n+4}$ . This series includes pentaborane(9),  $\text{B}_5\text{H}_9$ , and decaborane(14),  $\text{B}_{10}\text{H}_{14}$ .
- *Arachno*-boranes with a general formula of  $\text{B}_n\text{H}_{n+6}$ . The first member of this series is tetraborane(10),  $\text{B}_4\text{H}_{10}$ .

20 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  $\text{B}_5\text{H}_9$  when it was no longer needed, the US government treated it with steam to form a solution of boric acid ( $\text{H}_3\text{BO}_3$ ) 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

30 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 -

Examiner  
only

- (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 dm<sup>3</sup> at 273 K and 1 atm pressure.

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

- (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]

.....

.....

1095  
010007

Examiner  
only

- (d) Balance the equation for the reaction of pentaborane(9), B<sub>5</sub>H<sub>9</sub>, with steam (lines 18-20). [1]



- (e) The standard enthalpy change of formation of pentaborane(9) is +42.8 kJ mol<sup>-1</sup>. 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]

15

**Total Section A [40]**

**BLANK PAGE**

5. (a) Group II elements can only show an oxidation state of II, however Group IV elements can show oxidation states of II and IV in their compounds.

(i) State how the relative stability of these oxidation states changes as Group IV is descended and give a reason for this trend. [2]

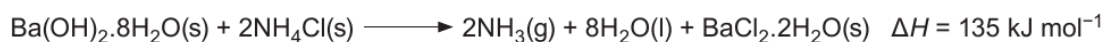
(ii) The characteristics of the Group IV elements and their compounds change significantly from carbon to lead. Show how this statement is true by comparing:

- the reactions, if any, of carbon dioxide and lead(II) oxide with acids and alkalis
- the reduction-oxidation properties of carbon monoxide and lead(IV) oxide.

Your answer should include any relevant chemical equations.

[6]  
QWC [1]

(b) Endothermic solid-solid reactions are rare in chemistry, but some do occur spontaneously. One such example is the reaction between barium hydroxide and ammonium chloride. The reaction can be represented as follows.



The entropy values of the compounds involved in this reaction are given below.

Compound	Ba(OH) <sub>2</sub> ·8H <sub>2</sub> O(s)	NH <sub>4</sub> Cl(s)	NH <sub>3</sub> (g)	H <sub>2</sub> O(l)	BaCl <sub>2</sub> ·2H <sub>2</sub> O(s)
Entropy / J K <sup>-1</sup> mol <sup>-1</sup>	427	95	192	70	203

(i) Explain why there is an increase in entropy for this reaction. [1]

(ii) Calculate the entropy change for this reaction. [1]

(iii) Calculate the free energy change, ΔG, for the reaction at 25 °C and explain why this reaction is feasible. [3]

- (c) The enthalpy change of formation of barium chloride,  $\text{BaCl}_2$ , can be determined indirectly using a Born-Haber cycle.

Use the data given below to calculate the enthalpy change of formation of barium chloride in  $\text{kJ mol}^{-1}$ . [4]

Process	$\Delta H^\theta / \text{kJ mol}^{-1}$
$\text{Ba(s)} \longrightarrow \text{Ba(g)}$	176
$\frac{1}{2}\text{Cl}_2(\text{g}) \longrightarrow \text{Cl(g)}$	121
$\text{Ba(g)} \longrightarrow \text{Ba}^+(\text{g}) + \text{e}^-$	502
$\text{Ba}^+(\text{g}) \longrightarrow \text{Ba}^{2+}(\text{g}) + \text{e}^-$	966
$\text{Cl(g)} + \text{e}^- \longrightarrow \text{Cl}^-(\text{g})$	-364
$\text{Ba}^{2+}(\text{g}) + 2\text{Cl}^-(\text{g}) \longrightarrow \text{BaCl}_2(\text{s})$	-2018

- (d) Write the **formulae** of the chlorine-containing species that are produced when chlorine reacts with warm aqueous sodium hydroxide. [2]

Total [20]

**Total Section B [40]**

**END OF PAPER**

**BLANK PAGE**

**BLANK PAGE**

**END OF QUESTION PACK**

5 questions · 89 marks · ~2 h 22 min  
Source: WJEC CH5 (2008 modular spec, Jun 2010 – Jun 2016)  
Curated for WJEC Chemistry 2015 spec A2 Unit 3 – Topic 2 (3.3)

© WJEC CBAC Ltd. Pack layout © revise.wales for revision purposes only.