WJEC Chemistry A-level

1.6: The Periodic Table

Practice Questions

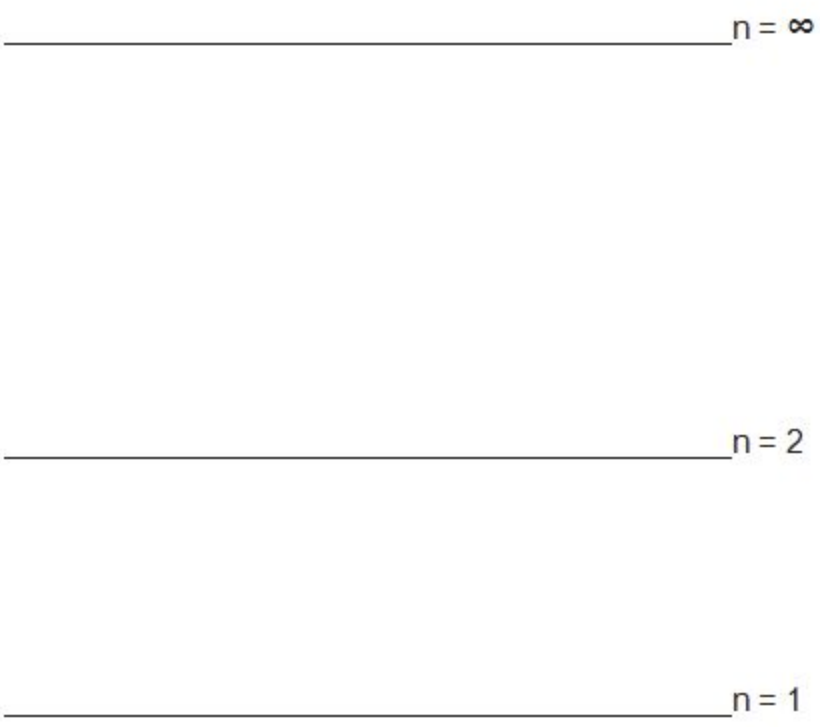
Wales Specification

1. (a) Hydrogen exists as three isotopes with relative masses of 1, 2 and 3.

State the similarities and differences in the composition of these specific isotopes.

[2]

(b) The first two electronic energy levels in a hydrogen atom are shown on the diagram.



(i) Complete the diagram to show energy levels n = 3, n = 4 and n = 5.

[1]

(iii) Mark with an arrow the energy change corresponding to the ionisation energy of hydrogen.

[2]

(c) A student said that the ionisation energy of hydrogen could be calculated using the Balmer Series of lines.

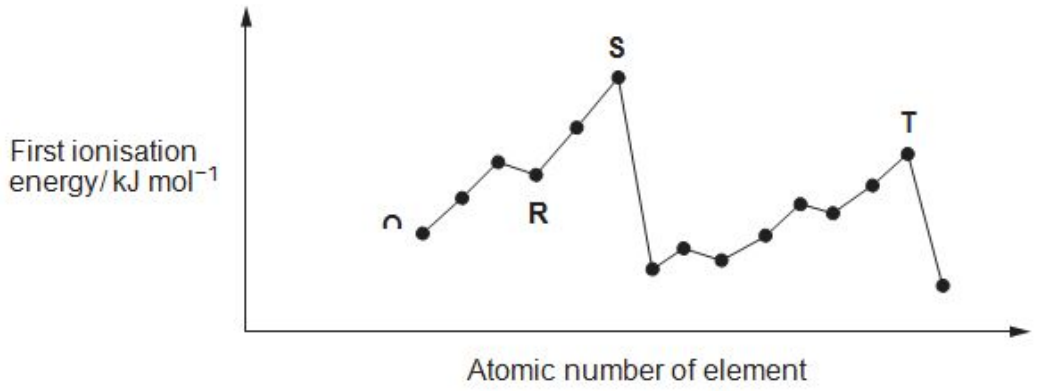
(i) In which part of the electromagnetic spectrum does the Balmer Series appear?

[1]

(ii) Explain whether or not this student was correct.

[2]

(d) The diagram shows part of a plot of the first ionisation energy of elements against their atomic numbers. Letters **Q**-**T** do **not** represent the symbols of the elements.



(i) Write the equation for the change occurring for the first ionisation energy of element **Q**.

[1]

(ii) In which group of the Periodic Table is element **R** found?

[1]

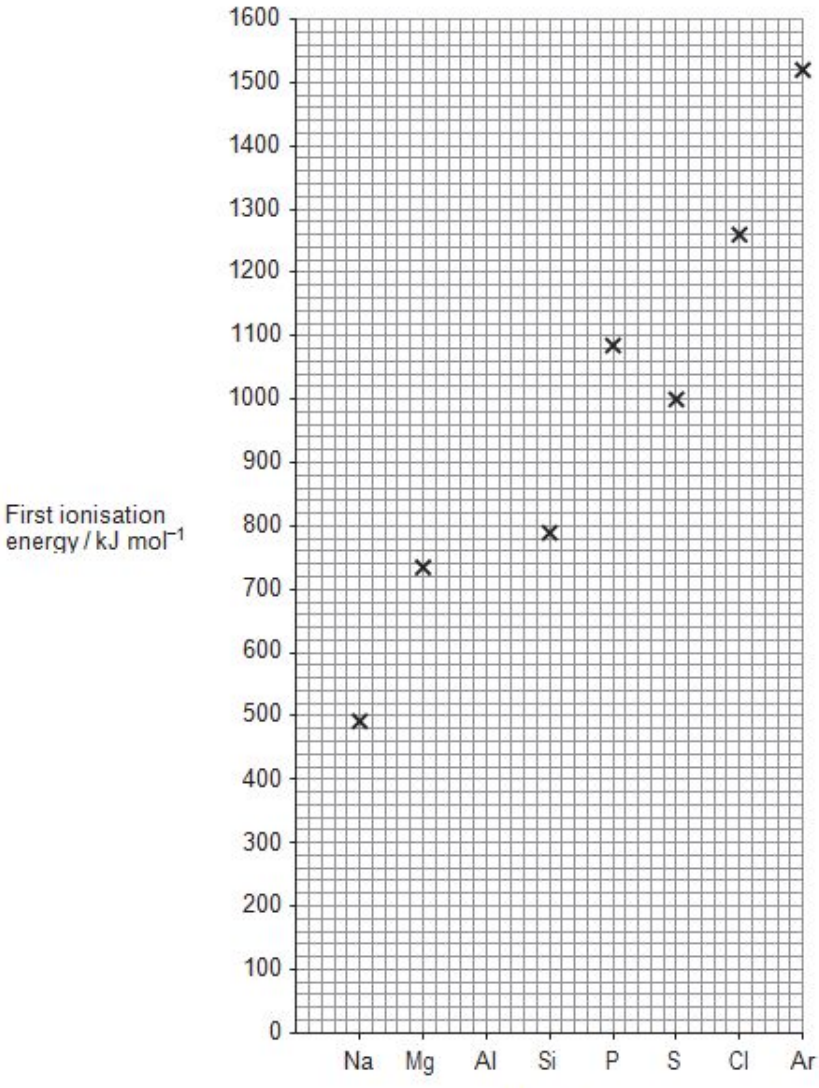
(iii) Explain why the first ionisation energy of **S** is greater than that of **T**.

[3] QWC [1]

(Total 14)

2. Ionisation energies and atomic spectra provide evidence for the arrangement of electrons in atoms.

(a) The following diagram shows the first ionisation energies of the Period 3 elements.



(i) State the meaning of the term *molar first ionisation energy*

[2]

(ii) Draw a cross on the diagram to suggest the first ionisation energy of aluminium.

[1]

(iii) Explain why the value of the first ionisation energy of sulfur is less than that of phosphorus.

[2]

(b) The table below gives some ionisation energies for magnesium

	1st	2nd	3rd	4th	5th
Ionisation energy / kJ mol^{-1}	736	1450		10500	13629

(i) Explain why the second ionisation energy is greater than the first.

[1]

(ii) Complete the table by suggesting a value for the third ionisation energy of magnesium.

[1]

(c) Explain briefly how the lines in the visible atomic emission spectrum of hydrogen are formed and why the lines become closer together at the high frequency end of the spectrum.

[4] QWC [1]

(Total 12)

3. Berian was asked to find the identity of a Group 1 metal hydroxide by titration.

He was told to use the following method.

1. Fill a burette with hydrochloric acid solution.
2. Accurately weigh about 1.14 g of the metal hydroxide.
3. Dissolve all the metal hydroxide in water, transfer the solution to a volumetric flask then add more water to make exactly 250 cm^3 of solution.
4. Accurately transfer 25.0 cm^3 of this solution into a conical flask.
5. Add 2-3 drops of a suitable indicator to this solution.
6. Carry out a rough titration of this solution with the hydrochloric acid.
7. Accurately repeat the titration several times and calculate a mean titre.

Berian's results are shown below:

Mass of metal hydroxide = 1.14 g

Concentration of acid solution = 0.730 g HCl in 100 cm^3 of water

Mean titre = 23.80 cm^3

(a) Give a reason why Berian does not simply add 1.14 g of metal hydroxide to 250 cm^3 of water.

[1]

(b) Name a suitable piece of apparatus for transferring 25.0 cm^3 of the metal hydroxide solution to a conical flask.

[1]

(c) State why he adds an indicator to this solution.

[1]

(d) Suggest why Berian was told to carry out a rough titration first.

[1]

(e) Explain why he carried out several titrations and calculated a mean value.

[1]

(f) The equation for the reaction between the metal hydroxide and hydrochloric acid is given below. M represents the symbol of the Group 1 metal.

$$MOH + HCl \longrightarrow MCl + H_2O$$

(i) Calculate the concentration, in mol dm^{-3}, of the HCl in the burette.

[2]

(ii) Calculate the number of moles of HCl used in the titration.

[1]

(iii) Deduce the number of moles of MOH in 25.0 cm^3 of the solution.

[1]

(iv) Calculate the total number of moles of MOH in the original solution.

[1]

(v) Calculate the relative molecular mass of MOH.

[1]

(vi) Deduce the Group 1 metal in the hydroxide.

[1]

(Total 12)

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

[1]

(Total 1)

5.

Halogens and their compounds take part in a wide variety of reactions.

(a) Give the chemical name of a chlorine-containing compound of commercial or industrial importance. State the use made of this compound. [1]

(b) Hydrogen reacts with iodine in a reversible reaction.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

An equilibrium was established at 300 K, in a vessel of volume 1 dm^3, and it was found that 0.311 mol of hydrogen, 0.311 mol of iodine and 0.011 mol of hydrogen iodide were present.

(i) Write the expression for the equilibrium constant in terms of concentration, K_c. [1]

(ii) Calculate the value of K_c at 300 K. [1]

K_c = ...

(iii) What are the units of K_c, if any? [1]

.....

(iv) Equilibria of H_2, I_2 and HI were set up at 500 K and 1000 K and it was found that the numerical values of K_c were 6.25×10^{-3} and 18.5×10^{-3} respectively.

Use these data to deduce the sign of ΔH for the forward reaction. Explain your reasoning. [3]

.....

.....

.....

.....

(c) When concentrated hydrochloric acid is added to a pink aqueous solution of cobalt(II) chloride, the colour changes to blue.

Cobalt takes part in an equilibrium reaction.

$$[Co(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CoCl_4]^{2-}(aq) + 6H_2O(l)$$

(i) What is the oxidation state of cobalt in $[CoCl_4]^{2-}$? [1]

.....

(ii) What type of bonding is present in $[CoCl_4]^{2-}$? [1]

.....

(iii) Use the equation to identify the ions responsible for the pink and blue colours described above. Explain why the colour change occurs when concentrated hydrochloric acid is added to the pink solution. [3]

.....

.....

.....

.....

(iv) Draw diagrams to clearly show the shape of the $[Co(H_2O)_6]^{2+}$ ion and the $[CoCl_4]^{2-}$ ion. [2]

$[Co(H_2O)_6]^{2+}$ $[CoCl_4]^{2-}$

Total [14]

6.

(a) A solution of calcium chloride was obtained by adding 0.40 g of calcium metal to 80 cm^3 of hydrochloric acid of concentration 0.20 mol dm^{-3}. The equation for the reaction is

$$Ca + 2HCl \longrightarrow CaCl_2 + H_2$$

(i) Use the information given to show that an excess of calcium metal was used.

[3]

(ii) State **one** observation made during the reaction apart from the mixture becoming warm.

[1]

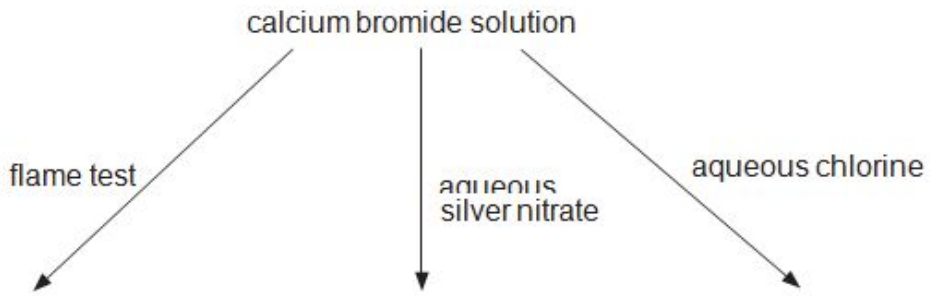
(b) A sample of a calcium compound **E** of mass 1.50 g was added to 200 cm^3 of cold water and the mixture heated until it all dissolved.

Use relevant information from the table to calculate the mass of compound **E** that crystallised when the solution was cooled to 0 °C. [2]

Solubility of compound **E** /g per 100 g of water	Temperature / °C
0.13	0
0.75	50
1.22	100

Mass that crystallised = ... g

(c) A student was given a solution of calcium bromide and asked to carry out the reactions shown in the diagram below.



(i) State the colour given in the flame test.

[1]

(ii) State what was seen when aqueous silver nitrate was added.

[1]

(iii) Give the **ionic** equation for the reaction occurring in (ii).

[1]

(iv) State what was seen when aqueous chlorine was added to the solution of calcium bromide.

[1]

(v) Explain why chlorine reacted as described in (iv). Your answer should include:

- the type of bonding and the species present in calcium bromide
- the type of reaction occurring
- why chlorine is able to react in this way
- an appropriate equation

[5] QWC [1]

(Total 16)

7. Ewan and Gwyneth are given four unlabelled bottles. They know that these contain the following four solutions:

potassium carbonate *sodium hydroxide* *barium chloride* *magnesium nitrate*

(a) Ewan predicted what will happen when each of the four solutions is added to the others, and presented this information in the grid below.

	magnesium nitrate	barium chloride	sodium hydroxide
potassium carbonate	white precipitate	white precipitate	no visible change
sodium hydroxide			
barium chloride			

(i) Complete the three empty boxes with the observations expected in each of these cases. [2]

(ii) Name the white precipitate formed when magnesium nitrate is mixed with potassium carbonate, and write an **ionic** equation for its formation. [2]

Name of precipitate:

. . . . . .

Ionic equation:

. . . . . .

(b) Gwyneth uses different tests to identify the four solutions. Each test allows her to distinguish between some of the solutions. For each test state the solution(s) that would give a visible change and the observation(s) that would be made.

(i) Addition of litmus solution

[1]

(ii) Flame test

[2]

(iii) Addition of sodium sulfate solution

[2]

(c) Ewan and Gwyneth are provided with a white solid that they believe to be sodium bromide or sodium iodide.

(i) They dissolve the solid in water to make a solution. Explain what occurs when an ionic solid such as sodium bromide dissolves in water.

[2]

(ii) Gwyneth uses aqueous silver nitrate to identify the solution. Give the observations expected when silver nitrate is added separately to solutions of sodium bromide and sodium iodide.

[2]

Observation with sodium bromide

Observation with sodium iodide

(iii) Ewan thinks that a further test is needed after addition of the silver nitrate to distinguish between sodium bromide and sodium iodide. Give the reagent and observations for this further test.

[2]

Reagent

Observation with sodium bromide

Observation with sodium iodide

(iv) When bromine water is added to a solution of sodium iodide, a reaction occurs. Write an equation for this reaction.

[1]

(Total 16)

8. Magnesium is best known for burning with a characteristic brilliant white light, however in industry it is the third most commonly used structural metal. The metal itself was first produced by Sir Humphry Davy in 1808 by the electrolysis of a mixture of magnesia and mercury oxide.

(a) Magnesium has three stable isotopes ^{24}Mg, ^{25}Mg and ^{26}Mg.

(i) State the number of protons present in an atom of ^{24}Mg. [1]

(ii) Deduce the number of neutrons present in an atom of ^{26}Mg. [1]

(iii) In order to calculate the relative atomic mass of magnesium, what would you need to know in addition to the relative mass of each isotope? [1]

(b) Magnesium also has a radioactive isotope ^{28}Mg which has a half-life of 21 hours.

(i) If you started with 2.0 g of ^{28}Mg, calculate the mass of this isotope remaining after 84 hours. [1]

(ii) Name **one** useful radioactive isotope and briefly describe how it is used in medicine, industry or analysis. [2]

(c) In order to obtain a mass spectrum of a gaseous sample of magnesium, the sample must be ionised.

(i) State how the magnesium atoms are ionised in the sample.

[1]

(ii) Give a reason why it is necessary to ionise the magnesium atoms in the sample.

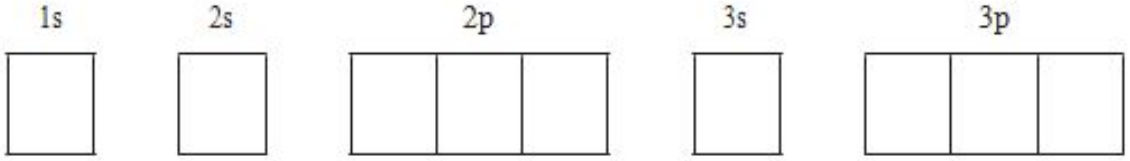
[1]

(iii) State how the ions of magnesium are separated.

[1]

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

By inserting arrows to represent electrons, complete the boxes below to show the electronic configuration of a nitride ion, N^{3-}. [1]



(e) Magnesium nitride reacts with water to form magnesium hydroxide and ammonia.

(i) Balance the equation above. [1]

(ii) Calculate the minimum mass of magnesium nitride required to form 1.75 g of magnesium hydroxide, giving your answer to **three** significant figures. [3]

(Total 14)

9. Calcium is present in teeth in the form of calcium phosphates. These do not react with water. The element calcium, however, reacts with water to produce calcium hydroxide and hydrogen gas.

$$Ca(s) + 2H_2O(1) \longrightarrow Ca(OH)_2(aq) + H_2(g)$$

(a) A student investigated the reaction between calcium and cold water. He added 2.0 g of calcium to some water and collected the hydrogen gas formed.

Draw a labelled diagram of an apparatus that would be suitable for carrying out this reaction and measuring the volume of hydrogen produced.

[2]

(b) The student repeated the reaction using the same mass of barium. He noticed that the volume of gas, still at the same temperature and pressure, was less.

(i) Give the reason why the volume of gas produced was less.

[1]

(ii) Suggest another difference that the student would observe when barium was used in place of calcium.

Explain your answer

[2]

(c) The student did not label the flasks containing the solutions after the reactions with calcium and with barium.
Give a test that would distinguish between these solutions. Include the result of your test for both solutions.

[2]

(d) Calcium oxide also reacts with water to produce calcium hydroxide. Draw a dot and cross diagram to show the bonding in calcium oxide. Show only the electrons in outer shells.

[2]

(e) Barium, as barium sulfate, is used medicinally in barium meals since it is insoluble in water and shows on x-ray images.

(i) Starting from the solution of barium hydroxide the student produced in *(b)*, describe how he could obtain a pure, dry sample of barium sulfate.
You should include an **ionic** equation for the reaction.

[3]

(ii) Calculate the maximum mass of barium sulfate that the student could make, starting with 2.0 g of barium.

[2]

Mass = ... g **(Total 14)**

10. (a) Sodium and potassium both react with cold water but their reactivities are different. The first ionisation energy affects the reactivity of Group 1 elements.

(i) Give an observation that shows the difference in reactivity with cold water between sodium and potassium

[1]

(ii) Describe the trend in the first ionisation energy of Group 1 elements and explain why this trend occurs.

[2]

(iii) Explain how this trend affects the reactivity of Group 1 elements.

[1]

(b) A GCSE student said that, apart from metallic bonding, bonds were either ionic or covalent. An A level student said that this was not really true and that bonds could be intermediate between ionic and covalent.

(i) State **one** factor that governs what type of bond elements form and explain how this leads to different types of bonding.

[2]

(ii) Describe the electron density in each type of bond

[3]

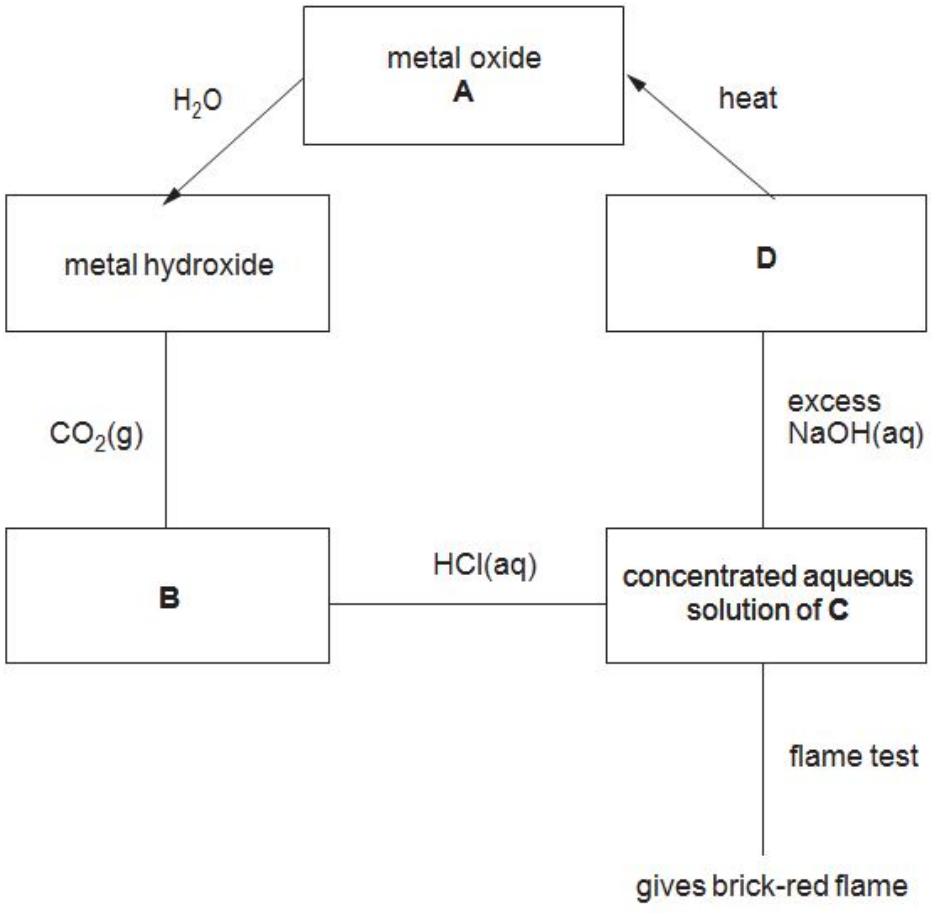
Ionic

Covalent

Intermediate

(c) Compound **A** is the oxide of a metal.

The diagram shows some reactions of compound **A**, and associated compounds, that can be carried out in the laboratory.



(i) What metal is present in compound **A**?

[1]

(ii) What compound containing the metal is present in the aqueous solution **C**?

[1]

(iii) Describe the appearance of the contents of the test tube with compound **D.**

[1]

(iv) Write the **ionic** equation for the reaction between solution **C** and aqueous sodium hydroxide.

[1]

(Total 13)