

4 Inorganic chemistry and the periodic table

Answers to Exam practice questions

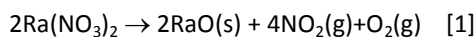
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- 1 a) Atomic radius increases down the group [1] because of the increasing number of inner full shells of electrons. [1] The more full shells the larger the atom. [1]
- b) First ionisation energies decrease down the group [1] because the shielding effect of inner shells means that in all the atoms the effective nuclear charge for the outer electrons is the same [1] but down the group the outer electrons get further away and so are held less strongly. [1]
- c) Thermal stability of carbonates increases down the group. [1] The greater the polarising power of the metal ion the more unstable the carbonate. [1] Down the group the radii of the $2+$ ions increase so their polarising power decreases. [1]
- 2 a) $\text{Cl}_2(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{ClO}^-(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$ [1]
Chlorine (oxidation state 0) is both oxidised to the +1 state and reduced to the -1 state. [1]
- b) $3\text{ClO}^-(\text{aq}) \rightarrow \text{ClO}_3^-(\text{aq}) + 2\text{Cl}^-(\text{aq})$ [2]
- c) $4\text{ClO}_3^-(\text{s}) \rightarrow 3\text{ClO}_4^-(\text{s}) + \text{Cl}^-(\text{s})$ [1]
Chlorine in the +5 state is oxidised to the +7 state [1] while being reduced to the -1 state. [1]
- 3 a) X is sodium nitrate. Yellow flame indicates sodium. [1] Sodium hydroxide is soluble. [1] The gas is oxygen. [1] This could be from a nitrate decomposing to the nitrite. [1]
- b) Y is barium chloride. Green flame suggests barium. [1] The white precipitate with silver nitrate indicates chloride ions. [1]
- c) Z is potassium bromide. Mauve flame suggests potassium. [1] Potassium and bromide ions do not affect the pH of solutions. [1] The cream precipitate with silver nitrate indicates bromide ions. Silver bromide dissolves in concentrated ammonia. [1] Chlorine oxidises colourless bromide ions to orange bromine. [1]
- 4 a) Expect radium to burn brightly in oxygen forming a white oxide (or peroxide) [1] RaO/RaO_2 [1]
 $2\text{Ra}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{RaO}(\text{s})$ or $\text{Ra}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{RaO}_2(\text{s})$ [1]
- b) Rapid reaction of radium with water producing a colourless gas, hydrogen [1] and an alkaline solution of the hydroxide. [1]
 $\text{Ra}(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{Ra}(\text{OH})_2(\text{aq}) + \text{H}_2(\text{g})$ [1]
- c) Expect radium oxide to react exothermically with water and to produce a strongly alkaline solution [1] of the hydroxide $\text{Ra}(\text{OH})_2(\text{aq})$. [1]
 $\text{RaO}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{Ra}(\text{OH})_2(\text{aq})$ [1]
- d) Expect radium hydroxide to neutralise dilute hydrochloric acid to produce a colourless solution [1] of the chloride, RaCl_2 . [1]
 $\text{Ra}(\text{OH})_2(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow \text{RaCl}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$ [1]

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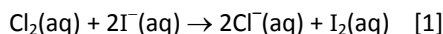
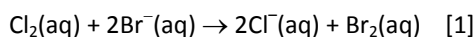
- e) Expect radium sulfate to be insoluble [1] because the trend is for the sulfates to become less soluble down the group and barium sulfate is insoluble. [1]
- f) Expect radium nitrate to need strong heating before it decomposes. Likely to behave similarly to barium or lithium and decompose to give the oxide, nitrogen dioxide and oxygen. [1]
Nitrogen dioxide is a brown gas. Oxygen relights a glowing splint. [1]



- 5 a) This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained line of reasoning. Assess the quality of the answer taking into account both the key points made (*up to 4 marks*) and the logic and coherence of the discussion (*up to 2 marks*).

Points to make in an answer:

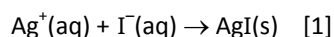
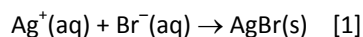
- Solubility of hydroxides increases down the group.
 - Solubility of nitrates decreases down the group.
 - Solubility of carbonates decreases down the group.
 - The polyatomic nitrate and carbonate ions are relatively large ...
 - ... compared to the hydroxide ion, which consists of two relatively small atoms.
 - On the basis of these examples the generalisation is true.
- b) Fluorine is an element in the second period. Its atoms and ions are relatively small [1]. In line with the generalisation this means that solubility is expected to increase down the group from magnesium fluoride to barium fluoride. [1]
- 6 a) Expect astatine to be a solid at room temperature. [1] Iodine is a solid and astatine has larger molecules with more electrons so that it is more polarisable [1] giving rise to strong London forces between the molecules. [1]
- b) Expect chlorine to oxidise astatide ions to astatine molecules [1] just as chlorine oxidises iodide ions. Oxidising power of the halogens decreases down the group. [1]
- c) Little or no hydrogen astatide expected to form. [1] The astatide ion is the strongest reducing agent of the halide ions [1] and can be expected to reduce concentrated sulfuric acid to sulfur and hydrogen sulfide. [1]
- d) Silver astatide might be an even brighter yellow than silver iodide. [1] Trend in the solubility of AgX in concentrated ammonia solution decreases down the group so At will not dissolve. [1]
- 7 a) Adding aqueous chlorine displaces orange bromine from a solution of a bromide. [1] On adding aqueous chlorine to a solution of an iodide the mixture turns to a dark yellow-brown colour. [1] Adding a little of an organic solvent such as hexane to the mixtures helps to distinguish the results. Bromine is orange when dissolved in hexane. [1] Iodine is violet. [1]



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b) Silver nitrate gives a cream precipitate with a solution of a bromide and a yellow precipitate with a solution of an iodide. [1] Adding ammonia solution helps to distinguish the precipitates. [1] Silver bromide dissolves in concentrated aqueous ammonia solution. [1] Silver iodide does not dissolve. [1]



c) Adding concentrated sulfuric acid to the solid salts gives distinctive results. A bromide gives off orange bromine vapours as the bromide ions reduce H_2SO_4 to SO_2 . [1] Some hydrogen bromide gas forms too. Sulfur dioxide turns acid dichromate(vi) paper from orange to green. [1] Hydrogen bromide fumes in moist air. [1]



With an iodide the products are iodine vapour, hydrogen sulfide and sulfur. [1]

Very little hydrogen iodide forms. The hydrogen sulfide can be detected by its foul smell. [1]

8 $\text{I}^- > \text{Br}^- > \text{Cl}^-$

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained line of reasoning. Assess the quality of the answer taking into account both the key points made (*up to 4 marks*) and the logic and coherence of the discussion (*up to 2 marks*).

Possible examples (one or the other or both):

- Halide ions in solution reducing halogen molecules
- Reactions of concentrated sulfuric acid with potassium halides.

Key components of the answer:

- Description of procedure (to allow comparison of Cl^- , Br^- and I^-)
- Observations for tests
- Equations for reactions
- Interpretation in terms of reducing power to establish trend.

9 a) i) $\text{CaF}_2(\text{s}) + \text{H}_2\text{SO}_4(\text{l}) \rightarrow \text{CaSO}_4(\text{s}) + \text{HF}(\text{g}) \quad [1]$

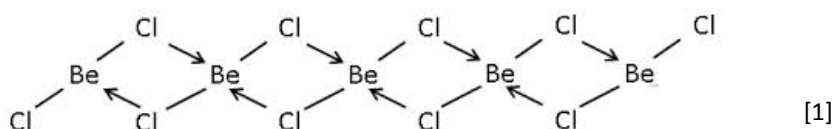
ii) Fluorine is so electronegative that the electrons in the H–F bond are drawn strongly towards the F atom. [1] This means that there is hydrogen bonding in H–F unlike the other hydrogen halides. [1] Hydrogen bonds are relatively strong intermolecular forces compared to the London forces and dipole–dipole attractions in the other hydrogen halides. [1]

b) i) The reactions between chlorine and alkanes are substitution reactions. [1] The products are halogenoalkanes and HCl. [1] Halogenoalkanes are important chemical intermediates so they are manufactured on a large scale producing large amounts of HCl as a by-product. [1]

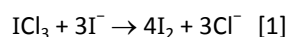
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- ii) NaOH is made by the electrolysis of sodium chloride solution [1] which produces hydrogen at one electrode and chlorine at the other. [1] The two gases are easily purified (largely by removing water vapour). [1]
- iii) The reaction of hydrogen with chlorine is highly exothermic and can be explosive. [1]
- iv) Any suitable example [1] such as the manufacture of fine chemicals such as drugs, or in sensitive chemical analysis.
- c) Bromide ions are stronger reducing agents than chloride ions [1]; they reduce sulfuric acid to sulfur dioxide and are oxidised to bromine as they do so. [1]
- 10 a) The boiling temperature of beryllium chloride is very much lower than that of chlorides of the other metals in the group. [1] BeCl_2 vaporises much more easily than the other chlorides. [1]
- b) The ionic radius of beryllium ($1s^2$) is much smaller than that of magnesium ($1s^2 2s^2 2p^6$). [1] This means the beryllium ion has a very high polarising power. [1] This means that the bonding in beryllium chloride is substantially covalent. [1] It vaporises relatively easily to give BeCl_2 molecules. [1]
- c) There are only two electrons in the outer shell of a Be atom. [1] The atom forms two covalent bonds with chlorine atoms. [1] When it does so, there are no lone pairs in the outer shell of the Be atom, just two bonding pairs, so these arrange themselves as far apart as possible with a bond angle of 180° . [1]
- d) The beryllium chloride molecules align so that each chlorine atom forms a covalent bond with one beryllium atom and a dative covalent bond with another Be atom [1]. Thus each Be atom is linked to chlorine atoms by two covalent bonds and two dative covalent bonds. [1] There are no lone pairs on the Be atoms and so the four bonds are arranged tetrahedrally around the Be atom. [1]



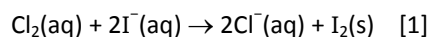
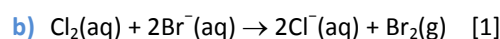
- 11 By inspection, if $x = 3$ [1], one iodine atom is reduced from oxidation state +3 to 0 [1] while three iodide ion are oxidised to iodine [1]. There is no change to the oxidation state of chlorine.



The reaction of iodine with chlorine: $\text{I}_2(\text{s}) + 3\text{Cl}_2 \rightarrow 2\text{ICl}_3$ [1]

Iodine is oxidised. Chlorine is reduced. [1]

- 12 a) The grey precipitate is iodine displaced by chlorine. [1] The orange-brown fumes are bromine displaced by chlorine. [1] The mixture contains potassium bromide and potassium iodide. [1]



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- c) The initial precipitate is a mixture of AgBr and AgI [1]. Treatment with concentrated ammonia dissolves the AgBr to leave only AgI. [1]

Mass of AgI precipitated = 0.176 g

Amount of AgI precipitated = $0.176 \text{ g} \div 234.8 \text{ g mol}^{-1} = 0.000750 \text{ mol}$ [1]

Mass of KI in the 0.214 g sample = $0.000750 \text{ mol} \times 166 \text{ g mol}^{-1} = 0.124 \text{ g}$ [1]

Percentage of KI in the sample = $(0.124 \text{ g} \div 0.214 \text{ g}) \times 100\% = 57.9\%$ [1]

The rest of the sample is KBr, so its percentage in the sample = 42.1% [1]

(The same calculation can be worked through on the basis of the mass of AgBr.)