MEGA LECTURE · A LEVEL CHEMISTRY

Chapter 9: Group 7, the Halogens

OCR A Level Chemistry A (H432) — Structured Practice Worksheet

SPECIFICATION	TOTAL MARKS	SUGGESTED TIME
3.1.3 Group 7: oxidising power, displacement, disproportionation, halide tests, uses	88	1 hour 50 minutes

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Instructions to candidates

- Answer **all** questions in the spaces provided.
- Halogens: fluorine, chlorine, bromine, iodine.
- Marks are shown in brackets [ ] at the end of each part.

Question 1 — Trends in the halogens 3.1.3

a. Describe the trend in melting and boiling point down Group 7, and state the physical state (at room temperature) of chlorine, bromine and iodine. **[2]**

b. Explain the trend in boiling point down Group 7 in terms of van der Waals forces. **[3]**

c. Describe the trend in oxidising power (reactivity) of the halogens going down the group. **[2]**

d. Explain the trend in oxidising power down the group in terms of atomic radius and shielding. **[3]**

Question 1 total: 10 marks

Question 2 — Displacement reactions 3.1.3

a. Chlorine water is added to potassium bromide solution. Write the ionic equation for the reaction that occurs. **[2]**

b. State the colour change observed in the reaction in (a). **[2]**

c. Explain, in terms of oxidation numbers, why this reaction is a redox reaction. **[2]**

d. Predict, with a reason, what would be observed if chlorine water were added to potassium iodide solution instead. **[2]**

e. Predict, with a reason, what would be observed if iodine solution were added to potassium chloride solution. **[2]**

Question 2 total: 10 marks

Question 3 — Halide ion tests

3.1.3 / PAG

A student is given three unlabelled solutions: sodium chloride, sodium bromide, and sodium iodide.

a. State the reagent added to each solution to identify the halide present. **[2]**

b. State the observation (colour of precipitate) for each of the three halide ions. **[3]**

c. Write the ionic equation, with state symbols, for the reaction of silver nitrate with sodium chloride solution. **[3]**

d.

Describe a confirmatory test, using aqueous ammonia, to distinguish between the three silver halide precipitates, including the observations. **[3]**

e. Explain why dilute nitric acid is added to the solution before adding silver nitrate. **[2]**

Question 3 total: 13 marks

Question 4 — Halide ions as reducing agents

3.1.3

a. Describe the trend in reducing power of the halide ions going down the group, from fluoride to iodide. **[2]**

b. Explain this trend in terms of ionic radius and the attraction between the ion and its outer electrons. **[3]**

c. State which halide ion is the strongest reducing agent and which is the weakest. **[2]**

Question 4 total: 7 marks

Question 5 — Reactions of solid sodium halides with concentrated sulfuric acid

3.1.3 / PAG

Solid sodium halides react with concentrated sulfuric acid. The observations depend on the identity of the halide.

a. Write the equation for the reaction of solid sodium chloride with concentrated sulfuric acid, and state the observation. **[2]**

b.

Write the equation for the initial acid–base reaction of solid sodium bromide with concentrated sulfuric acid. **[2]**

c. The HBr produced is then oxidised by concentrated sulfuric acid. Write the equation for this redox reaction and state the observation (colour, gas). **[3]**

d. With solid sodium iodide, several redox products are observed, including a black solid and a gas with a "rotten egg" smell. Identify these two products and write the equation for the redox reaction between HI and concentrated sulfuric acid to form H_2S. **[3]**

e. Use oxidation numbers to explain why iodide is oxidised more easily than chloride by concentrated sulfuric acid. **[3]**

Question 5 total: 13 marks

Question 6 — Disproportionation of chlorine 3.1.3

a. Define *disproportionation*. **[1]**

b. Write the equation for the reaction of chlorine with cold dilute aqueous sodium hydroxide, and use oxidation numbers to show that this is a disproportionation reaction. **[4]**

c. Write the equation for the reaction of chlorine with water. **[2]**

d. State the industrial/domestic use of the reaction in (c) and explain its importance, referring to one of the products formed. **[3]**

e. Chlorine is also used to treat water in swimming pools, despite being toxic. Explain, briefly, why this use is considered an acceptable risk. **[2]**

Question 6 total: 12 marks

Question 7 — Halogens and Group 2: comparing reactivity trends 3.1.2 / 3.1.3

a. State how reactivity changes down Group 2 and how it changes down Group 7. **[2]**

b. Explain why these two trends are in opposite directions, in terms of what happens to electrons in each case (loss vs gain). **[3]**

c. Explain why increased shielding and atomic radius down a group makes a Group 2 metal a stronger reducing agent, but makes a Group 7 element a weaker oxidising agent. **[3]**

Question 7 total: 8 marks

Question 8 — Water treatment and risk–benefit 3.1.3

Chlorine gas is widely used to disinfect public drinking water supplies, even though chlorine itself is toxic and can produce trace amounts of potentially harmful chlorinated organic by-

products. Discuss the benefits and risks of chlorinating drinking water, and explain why water companies consider this an acceptable practice. **[6]**

This question is marked using a level of response.

Question 8 total: 6 marks

Question 9 — Extended calculation and practical

3.1.3 / PAG

a. Describe how you would carry out a test-tube experiment to confirm that a colourless gas produced in a reaction is chlorine, including the reagent used and the observation for a positive result. **[4]**

b. 25.0 cm^3 of a solution containing iodine is titrated with 0.100 mol dm^{-3} sodium thiosulfate solution, using starch indicator. The mean titre is 18.40 cm^3. $I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$. Calculate the concentration of iodine in the original solution. **[3]**

c. State the colour change observed at the endpoint of this titration. **[2]**

Question 9 total: 9 marks

PAPER TOTAL: 88 MARKS

MARK SCHEME — Chapter 9: Group 7, the Halogens

Award marks independently unless stated.

Q1 (a) [2]

- Melting and boiling point increase down the group. (1)
- Chlorine: gas; bromine: liquid; iodine: solid. (1)

Q1 (b) [3]

- Number of electrons per molecule increases down the group. (1)
- Strength of van der Waals forces between molecules increases. (1)
- More energy is needed to overcome these stronger forces, so boiling point increases. (1)

Q1 (c) [2]

- Oxidising power (reactivity) decreases down the group. (2, or 1 for partial)

Q1 (d) [3]

- Atomic radius increases down the group, and shielding increases. (1)
- Both effects outweigh the increasing nuclear charge, so the nucleus attracts an incoming electron less strongly. (1)
- The halogen atom gains an electron less readily, so oxidising power decreases down the group. (1)

Q2 (a) [2]

- $Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$ (1 species, 1 balancing/states)

Q2 (b) [2]

- Colourless (pale green) solution changes to orange. (2, or 1 for partial description)

Q2 (c) [2]

- Cl: 0 → −1 (reduced); Br: −1 → 0 (oxidised). (1)
- Both oxidation and reduction occur simultaneously, so it is a redox reaction. (1)

Q2 (d) [2]

- Colourless solution turns brown (iodine displaced). (1)
- Chlorine is a stronger oxidising agent than iodine (higher up the group), so it can displace iodide to iodine. (1)

Q2 (e) [2]

- No reaction / no visible change. (1)
- Iodine is a weaker oxidising agent than chlorine, so it cannot displace chloride ions (chlorine, being higher, is already the more reactive halogen). (1)

Q3 (a) [2]

- Dilute nitric acid, then aqueous silver nitrate. (2)

Q3 (b) [3]

- Chloride: white precipitate. (1)
- Bromide: cream precipitate. (1)
- Iodide: yellow precipitate. (1)

Q3 (c) [3]

- $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ (1 species, 1 charges, 1 state symbols)

Q3 (d) [3]

- Add dilute ammonia: AgCl dissolves (soluble); AgBr and AgI remain undissolved (insoluble). (1)
- Add concentrated ammonia: AgBr dissolves (soluble); AgI remains undissolved even in concentrated ammonia. (1)
- Correct overall conclusion that solubility in ammonia distinguishes all three precipitates in sequence. (1)

Q3 (e) [2]

- Dilute nitric acid removes/reacts with ions such as carbonate that would also give a precipitate with silver ions. (1)
- This prevents a false positive result. (1)

Q4 (a) [2]

- Reducing power of the halide ions increases going down the group (from F^- to I^-). (2, or 1 for partial)

Q4 (b) [3]

- Ionic radius increases down the group. (1)
- The outer electron (to be lost) is further from the nucleus and more shielded, so it is less strongly attracted. (1)
- The electron is lost more easily, so the halide ion is a stronger reducing agent down the group. (1)

Q4 (c) [2]

- Strongest reducing agent: I^-. (1)
- Weakest reducing agent: F^-. (1)

Q5 (a) [2]

- $NaCl(s) + H_2SO_4(l) \rightarrow NaHSO_4(s) + HCl(g)$ (1)
- Observation: steamy/misty white fumes of HCl. (1)

Q5 (b) [2]

- $NaBr(s) + H_2SO_4(l) \rightarrow NaHSO_4(s) + HBr(g)$ (1 species, 1 balancing)

Q5 (c) [3]

- $2HBr + H_2SO_4 \rightarrow Br_2 + SO_2 + 2H_2O$ (1)
- Observation: orange/brown fumes of bromine. (1)
- Choking/acidic gas (SO_2) also produced. (1)

Q5 (d) [3]

- Black solid: iodine (I_2). (1)
- "Rotten egg" gas: hydrogen sulfide, H_2S. (1)
- $8HI + H_2SO_4 \rightarrow 4I_2 + H_2S + 4H_2O$. (1)

Q5 (e) [3]

- Iodide has a larger ionic radius than chloride, and its outer electron is more shielded/further from the nucleus. (1)
- I^- loses an electron (is oxidised to I_2) much more readily than Cl^- (whose electron is more tightly held). (1)
- Cl^- is not oxidised by concentrated sulfuric acid (S stays at +6 in the acid–base reaction only), while I^- is oxidised, reducing S to lower oxidation states. (1)

Q6 (a) [1]

- A reaction in which the same element is simultaneously oxidised and reduced. (1)

Q6 (b) [4]

- $Cl_2 + 2NaOH \rightarrow NaCl + NaClO + H_2O$ (1 species, 1 balancing)
- Cl in Cl_2 = 0; Cl in NaCl = −1; Cl in NaClO = +1. (1)
- Chlorine is simultaneously oxidised (0 → +1) and reduced (0 → −1), confirming disproportionation. (1)

Q6 (c) [2]

- $Cl_2 + H_2O \rightleftharpoons HCl + HClO$ (1 species, 1 balancing)

Q6 (d) [3]

- Used in water treatment to make drinking water safe. (1)
- HClO (chloric(I) acid / hypochlorous acid) formed is a powerful antibacterial/disinfectant agent. (1)
- It kills harmful microorganisms/pathogens in the water, preventing the spread of waterborne disease. (1)

Q6 (e) [2]

- The concentration of chlorine used is very low/carefully controlled, so the health risk is minimal. (1)
- The benefit (killing harmful bacteria, preventing disease) is judged to outweigh the small risk from chlorine exposure. (1)

Q7 (a) [2]

- Group 2: reactivity increases down the group. (1)
- Group 7: reactivity (oxidising power) decreases down the group. (1)

Q7 (b) [3]

- Group 2 metals react by losing electrons (forming 2+ ions) — reactivity is about how easily electrons are lost. (1)
- Group 7 elements react by gaining electrons (forming 1− ions) — reactivity is about how easily electrons are gained. (1)
- Since these are opposite electron processes, the trends driven by radius/shielding act in opposite directions. (1)

Q7 (c) [3]

- Down Group 2, increased shielding/radius makes it easier to lose the outer electrons — a stronger reducing agent (more reactive metal). (1)
- Down Group 7, increased shielding/radius makes it harder to attract/gain an extra electron into the outer shell. (1)
- A weaker attraction for an incoming electron means a weaker oxidising agent (less reactive non-metal). (1)

Q8 [6] — Level of response

- **Level 3 (5–6):** Discusses specific, correct benefits and risks with balanced reasoning, and reaches a justified conclusion about acceptability.
- **Level 2 (3–4):** Identifies at least one correct benefit and one correct risk with some explanation.
- **Level 1 (1–2):** Generic or one-sided statement with limited chemical reasoning.

Indicative content: *Benefits — chlorine kills harmful bacteria and pathogens, preventing waterborne diseases such as cholera and typhoid, protecting large populations cheaply and reliably. Risks — chlorine gas is toxic in high concentration; it can react with organic matter in water to form trace chlorinated by-products (e.g. trihalomethanes), some of which are linked to health concerns at high doses. Conclusion — the concentrations used in water treatment are very low and carefully monitored/controlled, so the risk is minimal; the proven public health benefit of preventing disease outbreaks is judged to far outweigh the small risk from chlorination, making it an acceptable and widely used practice.*

Q9 (a) [4]

- Hold a piece of damp blue litmus paper (or damp starch-iodide paper) at the mouth of the test tube. (2)
- Positive result with litmus: paper turns red then bleaches white. (1)
  - *Accept damp starch-iodide paper turning blue-black.*
- Alternative: chlorine is a pale green/yellow-green gas with a choking smell (1 alternative observation-based mark, capped at 4 total).

Q9 (b) [3]

- $n(S_2O_3^{2-}) = 0.01840 \times 0.100 = 1.84 \times 10^{-3}$ mol (1)
- $n(I_2) = 1.84 \times 10^{-3} \div 2 = 9.20 \times 10^{-4}$ mol (1)
- $c(I_2) = 9.20 \times 10^{-4} \div 0.0250 = 0.0368$ mol dm^{-3}. (1)

Q9 (c) [2]

- The solution turns from blue-black to colourless. (2)

END OF MARK SCHEME · 88 marks