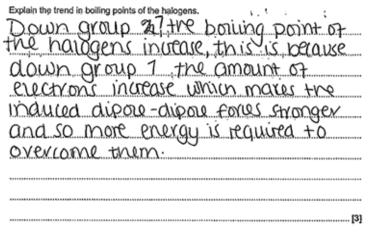
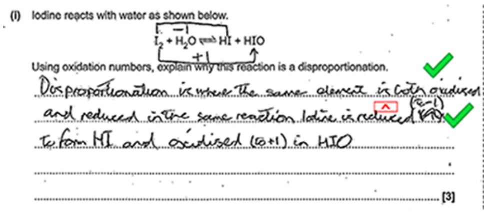
Mark scheme – The Halogens

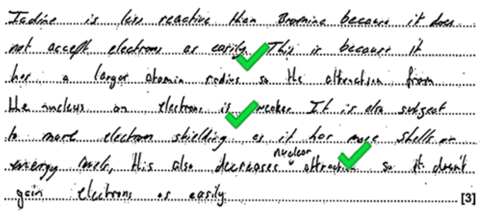
Question			Answer/Indicative content	Marks	Guidance
1	a		**Interpretation of Results** Orange contains bromine **AND** no reaction **AND** violet contains iodine ✓ **Ionic equation** $Br_2 + 2I^- \rightarrow 2Br^- + I_2$ ✓ **Reactivity (down the group)** Reactivity decreases **AND** oxidising power decreases **OR** gains electrons less easily **OR** forms negative ion/1– ion less easily **OR** less energy released when electron **gained** ✓ **OR** more negative electron affinity **Size/shells/shielding (down the group)** Greater atomic radius **OR** more shells **OR** more shielding ✓ **Attraction (down the group)** Less **nuclear** attraction down the group ✓	5 (AO 2.3×1) (AO 2.6×1) (AO 1.1×3)	Results can be interpreted anywhere in answer. **ALLOW** multiples, e.g. $\frac{1}{2}Br_2 + I^- \rightarrow Br^- + \frac{1}{2}I^2$ **IGNORE** other halogen/halide equations **IGNORE** state symbols **ALLOW** ORA **DO NOT ALLOW** idea of losing electrons/ionisation energy **IGNORE** chlorine is the most electronegative **IGNORE** explanations in terms of displacement **Examiner's Comments** This question required the candidate to explain the reactivity of the halogens given experimental observations. Higher-attaining candidates were able to explain the observations with ionic equations and explain the reactivity in terms of gaining electrons. Some candidates did not associate the colour with the halogen and linked it with the halide ion, but then did explain the trend in reactivity due to the ability to gain electrons. Lower-attaining candidates explained the reaction in terms of displacement (which was ignored) and they did not proceed with ionic equations or describe the ability to gain electrons. **Misconception** Some candidates linked the ability to gain electrons to ionisation energy rather than electron affinity. The colour of the organic layer was also associated with the halide ion rather than the halogen. **OCR support**

					Further guidance can be found in the AS Level delivery guide 'Theme: Patterns' (Group 2 and Group 17): https:/www.ocr.org.uk/Images/231740-patterns.pdf
	b		*Benefit **AND** risk required for **ONE** mark* **Benefit:** kills bacteria ✓ **AND** **Risk:** toxic/poisonous **OR** forms chlorinated hydrocarbons **OR** forms carcinogens/toxic compounds ✓	1 (AO 1.1)	**ALLOW** kills micro-organisms **OR** kills pathogens **OR** kills viruses **OR** sterilises/disinfects water **IGNORE** antiseptic, reduces risk of disease, cleans water **IGNORE** 'harmful'/'dangerous' **IGNORE** chlorine is carcinogenic/ dangerous for health/causes breathing problems
			Total	**6**	
2		i	Sodium bromate(V) ✓	1 (AO2.5×1)	**Examiner's Comments** Very few candidates scored this mark. Although a number of candidates did give sodium bromate as the answer (with the omission of the oxidation state), many other answers were seen suggesting candidates are not aware of naming conventions for inorganic compounds.
		ii	Br is oxidised **AND** reduced **OR** Br oxidation number is increased and decreased ✓ Br is oxidised from 0 to +5 ✓ Br is reduced from 0 to –1 ✓	3 (AO1.1×1) (AO2.2×2)	**ALLOW** same element is both oxidised and reduced **ALLOW 1 mark** if all 3 oxidation numbers are correct (even if oxidation/reduction incorrectly assigned) **Examiner's Comments** This is the first time in a reformed chemistry AS paper that the question space has been left unstructured for oxidation number changes. The highest-attaining candidates set out their responses clearly, dealing with changes for oxidation and reduction separately, and giving the correct oxidation numbers. Some struggled to obtain an oxidation state of Br in $NaBrO_3$ as +5, suggesting +1 instead.
			Total	**4**	
3			**Electrons (down group)** number of **electrons** increases ✓	3 (AO1.1×3)	FULL ANNOTATIONS MUST BE USED -- **ALLOW** more **electron** shells

					IGNORE 'more shells' **OR** more (electron) shielding **IGNORE** comments about nuclear attraction, ionisation energy, etc.
			Type of intermolecular force (ANYWHERE) induced dipole(–dipole) interactions **OR** London forces ✓		**IGNORE** van der Waals' forces, vdw **IGNORE** abbreviations e.g. LDF, IDID
			Link of energy with intermolecular forces (ANYWHERE) (Down group,) more energy to break/overcome **intermolecular** forces **OR** more/stronger **intermolecular** forces ✓		**IGNORE** less energy needed to break 'bonds' **OR** less energy needed to break 'London forces' *Too vague – needs idea of '**between molecules**'* **IGNORE** 'covalent bonds' between atoms **BUT** response linking to breaking of covalent bonds is a **CON for last marking point ONLY**. __**Examiner's Comments**__ **Exemplar 4**  Explain the trend in boiling points of the halogens. Down group 7, the boiling point of the halogens increase, this is because down group 7 the amount of electrons increase which makes the induced dipole-dipole forces stronger and so more energy is required to overcome them. [3] This question discriminated well. Candidates were expected to link increasing boiling point down the group with the increasing number of electrons and stronger induced dipole–dipole forces or London forces between molecules that must be broken. To be given all 3 marks, candidates needed to show that intermolecular forces (or forces between molecules) are broken during boiling. This mark proved to be the most difficult. The response shows a typical response that did not include intermolecular forces. Lower attaining candidates often let themselves down by being unable to construct a well-reasoned, relevant response. Many discussed nuclear charge, shielding, atomic radius and the ease of losing or gaining an electron to produce a valid explanation for ionisation energy or electron gain trend but

					not for different boiling points. The contrast in the clarity of low- and high-attaining candidate responses was particularly pronounced for this question.
			Total	**3**	
4			**ASSUME** trend is down the group (unless stated otherwise) **Forces** London forces increase **OR** induced dipole(−dipole) interactions increase ✓ **Reason** (Number of) electrons increases ✓ **Link to energy and particles** More energy to break intermolecular forces **OR** to break London forces **OR** to break induced dipole(−dipole) interactions ✓	3	**FULL ANNOTATIONS MUST BE USED** ------------------------------------ **ALLOW** reverse argument throughout **IGNORE** van der Waals'/vdW forces **DO NOT ALLOW** hydrogen bonds **OR** permanent dipole(-dipole) interactions for first and third marking points **ALLOW** more (electron) shells **DO NOT ALLOW** covalent bonds break <u>**Examiner's Comments**</u> Most candidates realised that as the group is descended, each molecule has more electrons, resulting in stronger London forces (or greater induced dipole-dipole interactions), which require greater energy to overcome. Common errors included describing the intermolecular forces as van der Waals' forces or permanent dipoles; stating that more energy is needed to overcome bonds (there are covalent bonds in these molecules) having previously used the term forces or interactions; and relating boiling point to reactivity based upon ease of electron loss due to differences in nuclear attraction.
			Total	**3**	
5	a	i	**Disproportionation** Oxidation **AND** reduction of same element/iodine **OR** Iodine has been **oxidised** and Iodine has been **reduced** ✓ **Oxidation** from **0** to **+1** in H**IO** ✓ **Reduction** from **0** to **−1** in **HI** ✓	3	**ALLOW** I or I_2 for iodine **IGNORE** numbers around equation for oxidation states **ALLOW** 1− for −1 **AND** 1+ for +1 **NOTE** (for iodine/I_2) **from 0** only needs to be seen once, does not need to be stated twice **ALLOW** 1 mark for 3 ox nos correct but no mention of words **oxidation/reduction**: 0 in I_2 **AND** −1 in HI **AND** +1 in HIO

					ALLOW 1 mark for species missing: Iodine oxidised (from 0) to +1 **AND** iodine reduced (from 0) to −1 **Examiner's Comments** Most candidates were aware of disproportionation but lost marks by not stating the species or whether the process was oxidation or reduction. **Exemplar 2**  (i) Iodine reacts with water as shown below. $I_2 + H_2O \rightleftharpoons HI + HIO$ Using oxidation numbers, explain why this reaction is a disproportionation. Disproportionation is where the same element is both oxidised and reduced in the same reaction. Iodine is reduced (to −1) to form HI and oxidised (to +1) in HIO [3] Here the candidate has lost a mark for not stating the initial oxidation number of elemental iodine as 0.
		ii	Chlorine is toxic/poisonous **OR** forms halogenated hydrocarbons **OR** forms carcinogens/toxic compounds ✓	1	**ALLOW** (reacts with hydrocarbons to) form carcinogens/toxic compounds **IGNORE** • chlorine causes cancer • harmful/dangerous • chlorine causes breathing problems **Examiner's Comments** The majority of candidates stated that chlorine is toxic or forms carcinogens, although some stated that chlorine is a carcinogen which was not credited. 12
	b	i	$Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ ✓	1	**ALLOW** multiples **IGNORE** state symbols **Examiner's Comments** Around 50% of candidates answered this correctly. The most common error was not balancing the equation, and many did not know what an ionic equation was.
		ii	Iodine has a larger atomic radius ✓	3	**ORA** **ALLOW** iodine is larger / bromine is smaller

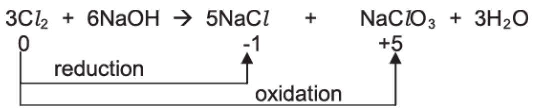
			Iodine has greater shielding / more shells ✓ Iodine has weaker / less **nuclear** attraction (on electron gained than bromine) ✓		**ALLOW** electron added to a shell further from the nucleus **ALLOW** bromine has greater **nuclear** attraction **IGNORE** 'gained less easily' for 'weaker attraction' **IGNORE** references to ionisation energy **DO NOT ALLOW** mention of losing electrons for M3 **ALLOW** 'pull' for 'attraction' **IGNORE** just 'greater attraction' **OR** greater force __**Examiner's Comments**__ This question was answered well by most candidates, although some omitted the word 'nucleus' when explaining attracting electrons, or answered in terms of losing electrons, and did not have the final marking point credited. **Exemplar 1**  Iodine is less reactive than Bromine because it does not accept electrons as easily. This is because it has a larger atomic radius so the attraction from the nucleus on electrons is weaker. It is also subject to more electron shielding as it has more shells or energy levels, this also decreases nuclear attraction so it doesn't gain electrons as easily [3] This candidate was credited all three marks. Some candidates managed to be credited for all 3 marks in one short sentence that covered all 3 marking points.
			Total	**8**	
6			$Br_2 + 2KOH \rightarrow KBr + KBrO + H_2O$ (1)	1	**allow** $3Br_2 + 6KOH \rightarrow 5KBr + KBrO_3 + 3H_2O$ **allow** ionic equation
			Total	**1**	

7		i	*Disproportionate:* oxidation and reduction of the same **element** ✓ *Redox:* Cl is oxidised from +5 (in $KClO_3$) to +7 (in $KClO_4$) ✓ Cl is reduced from +5 (in $KClO_3$) to −1 (in KCl) ✓	3	**ALLOW** 'chlorine' **OR** 'Cl' for same element **IGNORE** 'species' for 'element' **ALLOW** after number, e.g. 5+ **IGNORE** ionic charges, e.g. Cl^{5+} **IGNORE** '5' (signs required) **IGNORE** any reference to electron loss / gain (even if wrong) **ALLOW** one redox mark if oxidation numbers are correct but reduction / oxidation is incorrectly assigned **Examiner's Comments** The question asked candidates to state what disproportionation meant. Many candidates failed to give this statement, despite correctly identifying the change in oxidation number and correctly assigning the redox terms.
		ii	potassium chlorate(VII) ✓	1	Brackets required **Examiner's Comments** It was apparent that the idea of systematic naming of compounds was not known by many candidates. Of those who realised that Roman numerals were required, many showed uncertainty of the identity of the Roman numeral to be used or positioned the numeral at an inappropriate place within the name of the compound.
			Total	**4**	
8	a	i	Silver nitrate **OR** $AgNO_3$ ✓	1	**ALLOW** Ag^+ **IF** name correct, **IGNORE** an incorrect formula **IGNORE** acidified/HNO_3 **<u>Examiner's Comments</u>** Most candidates responded correctly with either the name of the reagent: silver nitrate, or its formula: $AgNO_3$.
		ii	Chloride: white (precipitate) **AND** Bromide: cream (precipitate) **AND** iodide: yellow (precipitate) ✓	1	All **three** required for the mark **<u>Examiner's Comments</u>** The colours of the silver halide precipitates

					were well known and very few candidates failed to score here. Where mistakes were made, it was to put the three colours in the wrong order or to show the colours of halogens in solution.
	b	i	$1s^22s^22p^63s^23p^63d^{10}4s^24p^6$ ✓ Look carefully at $1s^22s^22p^63s^23p^6$ – there may be a mistake	1	**ALLOW** 3d after $4s^2$ or after $4p^6$, e.g. $1s^22s^22p^63s^23p^64s^23d^{10}4p^6$ **ALLOW** upper case D, etc and subscripts, e.g. ......$4S_23D_1$ **DO NOT ALLOW** [Ar] as shorthand for $1s^22s^22p^63s^23p^6$ **<u>Examiner's Comments</u>** This part was generally answered well showing a good understanding of electron configuration. When incorrect, it was usually for giving the configuration of a bromine atom rather than a bromide ion, or the subtraction of an electron rather than addition giving $4p^4$.
		ii	$Cl^2 + 2Br^- \longrightarrow 2Cl^- + Br_2$ ✓ Chlorine/Cl/Cl_2 is more reactive/stronger oxidising agent **OR** reactivity decreases down group ✓	2	**ALLOW** multiples, e.g. $½Cl_2 + Br^- \longrightarrow Cl^- + ½ Br_2$ **IGNORE** state symbols **ALLOW** bromine is less reactive **IGNORE** explanation in terms of electronegativity **<u>Examiner's Comments</u>** Most candidates identified that chlorine was the more reactive element, although a significant number responded in terms of electronegativity. More commonly, it was the equation that was incorrect, usually unbalanced or with bromine reacting instead of chlorine.
	c		*Benefit **AND** risk required for mark* Benefits: kills **OR** removes bacteria **AND** Risk: toxic/poisonous **OR** forms chlorinated hydrocarbons **OR** forms carcinogens/toxic compounds ✓	1	**ALLOW** kills germs **OR** kills micro-organisms **OR** kills pathogens **OR** sterilises/disinfects **OR** makes water potable/ safe to drink **OR** purifies water **IGNORE** antiseptic, reduces risk of disease, cleans water **ALLOW** reduces risk of **water-born** diseases, e.g. cholera/typhoid/dysentery **IGNORE** 'harmful'/'dangerous' **IGNORE** chlorine is carcinogenic/ dangerous

					for health/causes breathing problems **Examiner's Comments** Most candidates scored this mark by stating a benefit (usually 'kills bacteria') and a risk (usually 'toxic' or 'forms carcinogenic compounds'). Vaguer terms such as 'harmful', 'can make you ill', etc, were not credited.
			Total	**6**	
9			M1 *Mixing of first pair of solutions* Adding (aqueous) barium chloride to bromine (water) **OR** $BaCl_2 + Br_2$ M2 *Mixing of second pair of solutions* Adding (aqueous) calcium iodide to bromine (water) **OR** $CaI_2 + Br_2$ **OR** Adding aqueous magnesium bromide to aqueous iodine **OR** $MgBr_2 + I_2$ *M3 Colours in cyclohexane* Colour for M1 is orange **OR** yellow **AND** Colour for M2 is purple **OR** violet **OR** mauve **OR** pink **OR** lilac *M4 Ionic equation mark* $Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ *M5 Use of M1 and* ***one*** *of M2 as only two experiments*	5	For M1 and M2 **ALLOW** any halide for the named halides in the question eg 'potassium chloride' for barium chloride 'potassium bromide' **DO NOT ALLOW** 'barium chlorine/BaCl' 'calcium iodine/CaI' 'magnesium bromine/MgBr' as the halide **DO NOT ALLOW** 'bromide' for 'bromine' **OR** 'iodide' for 'iodine' M1 can be seen anywhere M2 could be awarded from a correct ionic equation in M4 M2 can be seen anywhere If both M2 tests and M1 are given, this will nullify M5 M3 is given for the correct resultant colour of pairs of solution given in M1 and M2. If both possible pairs of solutions in M2 are given, both colours must be correct. **IGNORE** colours of other combinations of solutions **IGNORE** colours in the aqueous layer if stated **DO NOT ALLOW** other colours for M1 and M2 (eg iodine is brown) M4 can be awarded anywhere M4 also scores M2 if not already awarded **ALLOW** multiples **IGNORE** state symbols **IGNORE** $I_2 + 2Br^- \rightarrow I_2 + 2Br^-$ **IGNORE** $Br_2 + 2Cl^- \rightarrow Br_2 + 2Cl^-$ **DO NOT ALLOW** other ionic equations **DO NOT ALLOW** if more than two experiment are attempted even if pointless eg 'barium chloride + calcium iodide' Place the 'tick' for M5 against the sub-total mark, [5], at the bottom right hand side of the answer space

					Examiner's Comments Able candidates were able to provide full answers involving only two reactions, one ionic equation and correct colours of products in succinct form. Some candidates answered the question correctly then ignored the instruction to keep the number of reactions to a minimum and gave an unnecessary third confirmatory reaction. This question distinguished well for many weaker candidates were unable to produce chemically coherent responses. Suggestions for 'impossible' reactions such as adding magnesium bromide to calcium iodide were frequently seen from such candidates.
			Total	**5**	
10		i	***Equation*** $2NaOH + Cl_2 \rightarrow NaCl + NaClO + H_2O$ ✓ ***Conditions*** cold **AND** dilute (sodium hydroxide) ✓	2	**ALLOW** correct multiples **IGNORE** state symbols **ALLOW** room temperature OR ≤ 20°C for cold **Examiner's Comments** This question was perhaps not as well answered as it might have been and although some candidates had memorised the equation that was needed here, many clearly had not and more alarmingly such candidates were then content to suggest equations which were chemical nonsense. It was very uncommon indeed to see candidates pick up the second mark for giving the correct conditions required to form bleach from chlorine, with few realising that as well as being cold, the NaOH(aq) needs to be dilute.
		ii	*Definition of disproportionation mark* M1 (Disproportionation) is the (simultaneous) oxidation and reduction of the same element (in the same redox reaction) ✓ M2 Assigning of oxidation numbers Cl in Cl_2 is 0 **AND** Cl in NaCl is -1 **AND** Cl in $NaClO_3$ is +5 ✓ M3	3	**ALLOW** 'an element' **OR** 'a species' for 'the same element' Assume 'it' means disproportionation M1 can be awarded for 'chlorine is oxidised **and** reduced and this is disproportionation' **ALLOW** oxidation numbers written above the equation if not seen in the text but **IGNORE** oxidation numbers written above the equation if seen in the text **ALLOW** 1− **AND** 5 **AND** 5+ **DO NOT ALLOW** chloride in place of chlorine

			Chlorine has been oxidised from 0 to +5 AND Chlorine has been reduced from 0 to −1 ✓ ‘Chlorine has been oxidised from 0 in Cl_2 to +5 in $NaClO_3$ and chlorine has been reduced from 0 in Cl_2 to -1 in NaCl’ would secure M2 and M3  This diagram, along with a correct definition, would secure all three marks.		except for NaCl **DO NOT ALLOW** Cl^- in NaCl AND Cl^{5+} in $NaClO_3$ (ie do not allow ionic charges for oxidation numbers) **ALLOW** Cl **OR** Cl_2 for chlorine **DO NOT ALLOW** M2 if incorrect oxidation numbers of other elements are seen in the text eg H = +2 **ALLOW ECF** for third marks if ONE incorrect oxidation number is assigned but directional changes are correct eg Cl = 0 and -1 and +3 instead 0 and -1 and +5 **DO NOT ALLOW** ECF if two oxidation numbers are incorrectly assigned **IGNORE** references to electron loss / gain If oxidation numbers are correct ALLOW third mark for: chlorine is oxidised to form $NaClO_3$ **AND** chlorine is reduced to form NaCl **Examiner's Comments** The concept of disproportionation has been tested before and candidates were able to address this part of the question successfully. Weaker candidates met problems in assigning the oxidation numbers and in particular the Cl in $NaClO^3$ was frequently misassigned as +1. Another frequent mistake was to identify that both oxidation and reduction had taken place, but not to say which changes in the oxidation numbers of which species corresponded to each of these processes. A large number of candidates relied for one of their marks on the examiner marking their working shown above the equation. It should be stressed that a complete answer should aim to restate these key assignments of oxidation numbers within the text.
			Total	**5**	
11		i	$NaClO + 2HCl \rightarrow NaCl + Cl_2 + H_2O$ correct formulae of reactants, NaC*l* and chlorine (1) water and balancing (1)	2	**allow** $NaClO_3 + 6HCl \rightarrow NaCl + 3Cl_2 + 3H_2O$ for 1 mark
		ii	Test: add (a few drops of aqueous) silver nitrate (1)	2	**ignore** addition of dilute nitric acid before the $AgNO_3$

			Result: white ppt (1)		**ignore** redissolving in excess NH_3 or darkening of the ppt
		iii	separating funnel (1)	1	**allow** dropping pipette
			Total	**5**	
12		i	($1s^2$) $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^{10}$ $4s^2$ $4p^6$ ✓	1	**ALLOW** … $4s^2$ $3d^{10}4p^6$ **ALLOW** subscripts **AND** 3D **IGNORE** $1s^2$ seen twice **Examiner's Comments** Most candidates were awarded the mark available for the electron configuration of the bromide ion, but weaker responses included the electronic configuration of a bromine atom or of the ion, Br^+.
		ii	Cream **AND** precipitate ✓	1	**ALLOW** solid **OR** ppt for precipitate **IGNORE** 'does not dissolve' OR 'partially dissolves' **Examiner's Comments** Many candidates focused exclusively in their answers on the solubility of silver bromide in aqueous ammonia, writing as a result that the precipitate would remain, or that it would not dissolve and so not gaining the mark by omitting the colour of the precipitate.
		iii	$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$ ✓	1	Equation **AND** state symbols required **Examiner's Comments** The majority of candidates answered this question successfully with the only recurring error made being to omit some or all of the state symbols.
			Total	**3**	
13	a	i	(The solution would turn) yellow **OR** orange **OR** brown ✓	1	**ALLOW** shades and colours (eg dark yellow, yellow-orange) **DO NOT ALLOW** 'purple' **Examiner's Comments** The lack of correct responses suggested that candidates may not have met this simple experiment. Centres are advised to use a practical approach in their teaching wherever possible. The most common error here was to suggest that the solution would turn purple.

		ii	Cl_2 (g) + $2I^-$ (aq) → I_2 (aq) + $2Cl^-$ (aq) ✓	1	**ALLOW** multiples State symbols required **ALLOW** Cl_2(aq) **Examiner's Comments** The equation was correct in the majority of responses but the mark was lost by candidates due the state symbols not being included in their answer. Where state symbols were present it was very common to see I_2 given as a (g) rather than (aq). The reason for this is not clear but perhaps it stems from Cl_2 being (g) in the reactants.
	b		Cl_2 + 2NaOH → NaClO + NaCl + H_2O ✓	1	**ALLOW** multiples **IGNORE** state symbols **ALLOW** OH^- and ClO^-, i.e. $Cl_2 + 2OH^- \rightarrow ClO^- + Cl^- + H_2O$ **ALLOW** NaOCl **Examiner's Comments** This equation was directly from the specification and candidates were familiar with it. Errors in balancing were rare.
			Total	**3**	