

Chapter 9 — Group Properties and Elements

2. Questions for Short Answers

1. Why does it become easier to cut an alkali metal when we move from top to bottom in group 1?

Ans: As we move from top to bottom in group 1 the atomic size of the elements increases, because a new shell is added in each successive period. This increase in atomic size weakens the interatomic attraction between the metal atoms, so the atoms are held together less strongly. The metals therefore become softer as we go down the group and their melting points also decrease — from 180 °C for lithium down to only 28 °C for caesium. A softer metal with weaker bonding between its atoms can be cut more easily, which is why caesium is far easier to cut than lithium.

2. Predict the reactivity of potassium towards halogens.

Ans: Potassium is the third member of group 1 and its atom is larger than those of lithium and sodium, so its single outermost electron is held loosely and is lost very easily. The reactivity of alkali metals with halogens therefore increases down the group, and potassium reacts more vigorously than both lithium and sodium. With chlorine, lithium reacts on heating, sodium reacts vigorously and potassium reacts violently: $2K(s) + Cl_2(g) \rightarrow 2KCl(s)$. Potassium will react in the same violent manner with the other halogens as well, giving potassium halides which are ionic salts.

3. In the following reaction, chlorine acts as an oxidising agent. Which is the reducing agent? $Cl_2(aq) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(g)$

Ans: Sodium bromide, that is the bromide ion Br^- , is the reducing agent. Oxidation is the process in which an electron is lost and the substance which loses the electron is called the reducing agent. Here each bromide ion loses an electron and is oxidised to bromine, $2Br^- \rightarrow Br_2 + 2e^-$, while chlorine accepts those electrons and is reduced to chloride ions, $Cl_2 + 2e^- \rightarrow 2Cl^-$. Since chlorine has a greater oxidising power than bromine, it displaces the bromide ion from its compound.

4. Why does iodine exist in the solid state at room temperature?

Ans: Iodine exists as diatomic I_2 molecules which are non-polar, and these molecules are held together only by intermolecular forces of attraction. As we go down group 17 the atoms get larger because they have more electrons, so the molecules formed from these atoms attract each other with a stronger force. Iodine has the largest molecules of the common halogens, so the attraction between its molecules is the strongest and its melting and boiling points are the highest in the group. This is why iodine exists as shiny grey crystals at room temperature, while bromine is a liquid and chlorine and fluorine are gases. On warming, these crystals easily turn into dark purple vapours.

5. How does Ni catalyse the reaction involving hydrogenation of oil?

Ans: Nickel is a transition metal, and transition metals and their compounds function as catalysts in many important chemical reactions. They do so because the metal absorbs the other substances on its surface and activates them in this process. In the hydrogenation of oil, the hydrogen molecules and the oil molecules are adsorbed on the surface of the finely divided nickel, where their bonds are weakened and they are brought close together in the right position to react. Hydrogen is thus added to the oil much more easily, and the liquid oil is converted into solid margarine or banaspati ghee. The nickel itself is recovered unchanged at the end of the reaction.

3. Constructed Response Questions

1. Which noble gas should have the lowest boiling point and why?

Ans: Helium should have the lowest boiling point of all the noble gases. All noble elements are monatomic gases having very low boiling points, because their outermost shells are complete and their atoms do not bond with one another — the only forces between them are very weak intermolecular attractions. The strength of these attractions depends on the size of the atom: the bigger the atom, the stronger the attraction. Helium is the first noble gas and has the smallest atom of all, with only the s^2 configuration, so the attractions between its atoms are the weakest of the whole group. Very little energy is therefore needed to separate them, and helium boils at the lowest temperature.

2. Compare the reactions of alkali metals with chlorine.

Ans: All the alkali metals react with chlorine on heating to form metal chlorides, which are ionic salts, and the reaction becomes more vigorous as we go down the group: $2\text{Li(s)} + \text{Cl}_2\text{(g)} \rightarrow 2\text{LiCl(s)}$ on heating; $2\text{Na(s)} + \text{Cl}_2\text{(g)} \rightarrow 2\text{NaCl(s)}$, a vigorous reaction; $2\text{K(s)} + \text{Cl}_2\text{(g)} \rightarrow 2\text{KCl(s)}$, a violent reaction. The reason for this trend is that the atomic size increases down the group, so the single outermost electron is held less tightly and is lost more easily. Lithium, whose atom is the smallest and holds its electron most firmly, is therefore the least reactive of the three, and potassium is the most reactive.

3. Why are almost all the metals solids while non-metals generally exist as gases and solids?

Ans: In a metal the atoms are held together by a strong metallic bond, in which a sea of mobile electrons binds the positive ions together throughout the whole piece of metal. A great deal of energy is needed to break this bonding, so metals generally have high melting and boiling points and high densities, and they exist as solids at room temperature; only the alkali metals, being soft, and mercury, being a liquid, are exceptions. Non-metals, on the contrary, exist as small separate molecules. Within the molecule the atoms are joined by covalent bonds, but the forces between one molecule and another are very weak, so very little energy is needed to separate them. Non-metals therefore have low melting and boiling points and show a wide range of physical states — some are gases such as oxygen, nitrogen and chlorine, while those with larger molecules or giant structures, such as sulphur, carbon and iodine, are solids.

4. Name any three elements in the periodic table which exist as liquids.

Ans: Bromine is a liquid at room temperature; it is the fuming red-brown liquid of group 17. Mercury is the second, and it is the only metal which is a liquid at room temperature — all the other metals are lustrous solids. Caesium is the third: its melting point is only 28°C , so it melts in a warm room and exists as a liquid. Gallium, whose melting point is close to body temperature, and francium are also counted as liquids near room temperature.

5. Why are transition elements different from normal elements?

Ans: The elements present in the s and p blocks, that is groups 1 to 2 and 13 to 17, are called normal elements; in them all the inner shells are completely filled and only the outermost shell is incomplete. The transition elements lie at the centre of the periodic table, from group 3 to group 12, and in them the inner d-subshell is still in the process of being completed. This difference in the filling of the subshells gives the transition elements a set of properties which the normal elements do not have: they are all metals, they are often hard and have high densities, their melting and boiling points are high, they show variable oxidation states, the compounds they form are usually coloured, they are malleable and ductile, and they and their compounds act as catalysts in many important industrial reactions.

6. Compare the reactivity of chlorine and bromine as an oxidising agent.

Ans: Chlorine is a stronger oxidising agent than bromine. An oxidising agent is a substance which accepts electrons and is itself reduced, and the oxidising power of the halogens decreases down the group in the order $\text{Cl}_2 > \text{Br}_2 > \text{I}_2$. The chlorine atom is smaller than the bromine atom, so its nucleus attracts the incoming electron more strongly and it accepts an electron more readily. The proof of this is the displacement reaction: chlorine displaces the bromide ion from its compound, $\text{Cl}_2\text{(aq)} + 2\text{NaBr(aq)} \rightarrow 2\text{NaCl(aq)} + \text{Br}_2\text{(g)}$, but bromine cannot displace chloride from sodium chloride. Bromine is still able to displace iodine, $\text{Br}_2\text{(aq)} + 2\text{NaI(aq)} \rightarrow 2\text{NaBr(aq)} + \text{I}_2\text{(g)}$, so its oxidising power lies between that of chlorine and iodine.

7. Which element is the most reactive and which is the least reactive among halogens? Give two reasons to explain your answer.

Ans: Fluorine is the most reactive halogen and iodine is the least reactive; the reactivity of halogens decreases from top to bottom in the group. The first reason is atomic size: fluorine has the smallest atom of the group, so its nucleus is closest to the incoming electron and attracts it most strongly, making it accept an electron most easily; as the atomic size increases down the group, the tendency to accept an electron from other atoms decreases and the elements become less reactive. The second reason is oxidising power: the halogens are oxidising agents and their oxidising power falls in the order $\text{Cl}_2 > \text{Br}_2 > \text{I}_2$, with fluorine above chlorine, so a higher halogen can displace a lower one from its compound but never the other way round. Iodine, with the largest atom and the weakest oxidising power, is therefore the least reactive.