

Chapter 3 — Chemical Bonding

2. Questions for Short Answers

1. What type of elements loses their outer electron easily and what type of elements gain electron easily?

Ans: Metals lose their outer electrons easily. They have low ionization energy and form positive ions (cations); this is called their electropositive character. Alkali metals such as sodium and potassium are highly electropositive and lose an electron most easily, while alkaline earth metals such as magnesium and calcium lose their outer electrons less easily. Non-metals gain electrons easily. They have an affinity for electrons and form negative ions (anions), and are therefore called electronegative elements. Fluorine is the most electronegative element, followed by oxygen, nitrogen and chlorine.

2. Why do lower molecular mass covalent compounds exist as gases or low boiling liquids?

Ans: Lower molecular mass covalent compounds exist as discrete neutral molecules, and the intermolecular forces of attraction between these molecules are very weak. Very little energy is therefore needed to separate the molecules from one another, so these compounds have low melting and boiling points and exist as gases or as low boiling liquids at room temperature. Methane (CH_4), ammonia (NH_3), hydrogen sulphide (H_2S), hydrogen chloride (HCl), nitrogen dioxide (NO_2) and carbon dioxide (CO_2) are examples.

3. Give one example of an element which exists as a crystalline solid and it has covalent bonds between its atoms.

Ans: Diamond, which is a crystalline form of the element carbon. In diamond each carbon atom is surrounded by four other carbon atoms linked together by strong covalent bonds, giving a rigid three-dimensional structure. Graphite is another crystalline form of carbon with covalent bonds, and sulphur and phosphorus also exist as covalent solids.

4. Which property of metals makes them malleable and ductile?

Ans: In a metal the atoms are strongly held and arranged in the form of rows, one above the other, and the outer electrons move freely between them as a sea of mobile electrons. Because no electron belongs to any particular nucleus, the metallic bond is non-directional. When pressure is applied on the metal, the upper rows of atoms simply slip past the lower rows without breaking the metallic bond. The shape of the metal is therefore changed instead of the metal breaking, and metals can be easily drawn into wires and beaten into sheets.

5. Is coordinate covalent bond a strong bond?

Ans: Yes, a coordinate covalent bond is a strong bond. It differs from an ordinary covalent bond only in the way it is formed — the shared electron pair is donated by one atom (the donor) alone. Once the bond has been formed there remains no difference between a coordinate covalent bond and an ordinary covalent bond. For example, after the formation of the hydroxonium ion (H_3O^+) all three bonds of oxygen behave exactly alike, and in the ammonium ion (NH_4^+) all four N—H bonds behave exactly alike.

6. Write down dot and cross formula of HNO_3 .

Ans: In nitric acid the nitrogen atom is joined to three oxygen atoms: by a single covalent bond to the oxygen which carries the hydrogen, by a double covalent bond to the second oxygen, and by a coordinate covalent bond to the third oxygen. In the dot-and-cross diagram the shared pairs between N and O are shown as one dot and one cross, the double bond as two such shared pairs, and the coordinate bond as a pair contributed by nitrogen alone (shown by an arrow $\text{N} \rightarrow \text{O}$). The remaining electrons of each oxygen are drawn as lone pairs. Linear form: $\text{H} - \text{O} - \text{N} (= \text{O}) \rightarrow \text{O}$

3. Constructed Response Questions

1. Why is HF a liquid while HCl is a gas?

Ans: In hydrogen fluoride, hydrogen is covalently bonded to fluorine, which is the most electronegative element. The very large difference of electronegativity makes the H—F bond highly polar, and as a result strong hydrogen bonding develops between the HF molecules. In hydrogen chloride the difference of electronegativity between hydrogen and chlorine is much smaller, so only comparatively weak dipole-dipole forces exist between HCl molecules. Since the stronger the intermolecular forces the higher the boiling point, HF remains a liquid at room temperature while HCl is a gas.

2. Why are covalent compounds generally not soluble in water?

Ans: Most covalent compounds exist as discrete molecules which are non-polar or only weakly polar. Water, on the other hand, is a highly polar solvent; it can dissolve a substance only when its molecules can develop strong attractions with the particles of that substance and pull them apart, as it does with the ions of an ionic compound. Water molecules cannot develop such strong attractions with non-polar covalent molecules, so these molecules are not separated from one another and the compound remains undissolved. Such compounds are, however, usually soluble in non-polar solvents like ether, benzene and acetone.

3. How do metals conduct heat?

Ans: The outer electrons of metal atoms are held loosely by their nuclei and move freely in the vacant spaces between the positively charged ions, forming a sea of mobile electrons. When one end of a metal is heated, these free electrons at that end gain kinetic energy and begin to move more rapidly. They collide with other electrons and with the positive ions and pass on their energy to them, and in this way the energy is quickly carried from the hot end to the cooler end. The presence of freely moving electrons therefore makes metals good conductors of heat as well as of electricity.

4. How many oxides does nitrogen form? Write down the formulae of oxides.

Ans: Nitrogen forms five oxides: nitrous oxide N_2O , nitric oxide NO , dinitrogen trioxide N_2O_3 , nitrogen dioxide NO_2 (which also exists as dinitrogen tetroxide N_2O_4) and dinitrogen pentoxide N_2O_5 . Of these, nitrogen dioxide (NO_2) is mentioned in this chapter as a covalent compound which is a gas at room temperature.

5. What will happen if NaBr is treated with AgNO_3 in water?

Ans: Both sodium bromide and silver nitrate are ionic compounds and are soluble in water, so in solution they are present as free ions. When the two solutions are mixed, the positive ion of one compound reacts with the negative ion of the other: $\text{AgNO}_3(\text{aq}) + \text{NaBr}(\text{aq}) \rightarrow \text{AgBr}(\text{s}) + \text{Na}^+(\text{aq}) + \text{NO}_3^-(\text{aq})$. Silver bromide is insoluble in water, so it comes out of the aqueous solution as a pale yellow precipitate, exactly as silver chloride comes out as a white precipitate when sodium chloride is used.

6. Why does iodine exist as a solid while Cl_2 exists as a gas?

Ans: Iodine and chlorine both exist as non-polar covalent diatomic molecules, and their molecules are held together only by weak intermolecular forces of attraction. The iodine molecule is, however, much larger and much heavier than the chlorine molecule, so the intermolecular forces of attraction between iodine molecules are far stronger than those between chlorine molecules. The stronger the intermolecular forces, the higher the melting point of a solid; therefore iodine exists as a solid at room temperature while chlorine, whose intermolecular forces are very weak, exists as a gas.