Chapter 24 – Answers to end of chapter questions

1  a  The general trend from top to bottom of the group is a decrease in melting point. This is because of the change in structure and bonding. Diamond has a giant structure, which each atom joined to four others by strong covalent bonds in a giant network. Silicon has a similar structure. The metallic bonding in tin and lead is weaker than the bonding in diamond and silicon. This means that less energy is required to disrupt the structure when tin and lead melt than when diamond and silicon melt. This results in tin and lead having lower melting points than diamond and silicon.

   b  The general trend from top to bottom is a decrease in first ionisation energy. This is because, going down the group, the outer electrons are further from the nucleus and are shielded from the nucleus by a greater number of inner electron shells. This results in the outer electrons being less strongly attracted to the nucleus, and a consequent decrease in the first ionisation energy.

   c  Diamond is a non-conductor as it has no electrons that are free to move. Silicon and germanium are semi-conductors. Tin and lead are good conductors of electricity as their delocalised electrons are free to move and carry electrical charge.

2  a  i  Si(s) + 2Cl₂ (g) → SiCl₄ (l)

   ii  In a molecules of SiCl₄, a silicon atom is joined to four chlorine atoms by strong covalent bonds.

   b  Melting point increases going down the group. This is because the strength of the forces of attraction between the molecules increases going down the group. This results in more energy being required to disrupt the arrangement of molecules in the solid structure in order to make the substance melt.

   c  The reaction is more likely to form PbCl₂ since this change is more exothermic.

   d  SiCl₄ is made up of separate molecules, but PbCl₂ is made up of ions. The bonds between the oppositely charged ions in PbCl₂ are stronger than the intermolecular forces of attraction between SiCl₄ molecules. This means that PbCl₂ has the higher melting point.

   e  i  PbCl₄ → PbCl₂ + Cl₂

   ii  Pb⁴⁺ + 2e⁻ → Pb²⁺

   f  i  SiCl₄ (l) + 4H₂O (l) → Si(OH)₄ (aq) + 4HCl (g)

   ii  Hydrogen chloride gas

   iii  Chlorine atoms are more electronegative than silicon, so the negative electrons in the Si–Cl bonds move towards them, resulting in a δ⁺ charge on the silicon atom. During the reaction, the silicon atom is briefly surrounded by five pairs of electrons. The extra pair can be accommodated in unoccupied d orbitals.

   iv  CCl₄ does not react with water because carbon has no d orbitals to accommodate a fifth pair of electrons. There is also not enough space around the atom for an incoming water molecule.
3  a  Reduction of stannite, \( \text{SnO}_2 \), with carbon (coke)
\[
\text{SnO}_2(s) + 2\text{C}(s) \rightarrow \text{Sn}(l) + 2\text{CO}(g)
\]

b  Tin’s main uses are as a relatively inert metal and in alloys.
It is used to tin-plate steel for canning meats, soups, vegetables, etc. It is used in several alloys, e.g. solder (Sn/Pb) and pewter (Sn/Pb).

c  Tin is less reactive than zinc, so tin plate forms a thin layer of tin oxide much more slowly than zinc plating (galvanising) forms zinc oxide. However, once the surface plating is scratched, and the steel (iron) becomes exposed, a cell will be set up. In zinc plating, the zinc (more reactive than iron) will form \( \text{Zn}^{2+} \) ions and prevent the iron rusting, but in tin plating the tin is less reactive than iron, so \( \text{Fe}^{2+/3+} \) ions form and rusting occurs rapidly.

4  a  \( \text{Sn} + 2\text{I}_2 \rightarrow \text{SnI}_4 \)

b  \( \text{I}_2(s) \) is soluble in \( \text{CCl}_4(l) \); \( \text{SnI}_4 \) is soluble in hot \( \text{CCl}_4(l) \) but insoluble in cold \( \text{CCl}_4(l) \).

c  Number of moles Sn taken = \( \frac{4}{119} \) = 0.034

Number of moles \( \text{I}_2 \) taken = \( \frac{12.7}{254} \) = 0.05

:. Sn is in excess.

Yield of \( \text{SnI}_4 \) = 0.025 mol \( \times \) 627 = 15.68 g

d  When all the \( \text{I}_2 \) is used up and there is no purple coloration in the \( \text{CCl}_4 \).

e  Because \( \text{SnI}_4 \) will begin to crystallise at room temperature and clog up the funnel

f  To wash any \( \text{SnI}_4 \) off the excess tin

g  i  Tetrahedral  
   ii  Decomposes to \( \text{SnI}_2 \) and \( \text{I}_2 \) on heating

5  a  

b  ‘Iso-electronic’ means same number of electrons. \( \text{N}_2 \) is

c
\[ \text{CO}_2(g) + \text{C}(s) \rightarrow 2\text{CO}(g) \quad \Delta H = +172 \text{kJ} \]

\[ 2\text{C}(s) + \text{O}_2(g) \]

\[ \text{CO}(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H = -283 \text{kJ} \]

\[ \text{C}(s) + \text{O}_2(g) \]

\[ \text{CO}_2 \text{ is more stable than CO. CO}_2 \text{ is stable with respect to CO in the presence of C and much more stable than CO in the presence of oxygen.} \]