• A phase diagram of a pure compound has a triple point at 20 °C and 0.25 atm, a normal melting point at 25 °C, and a normal boiling point at 87 °C.

Describe what happens when the pressure is reduced from 2 atm to 0.05 atm at a constant temperature of 15 °C?

The data allows the phase diagram below to be drawn.

Arrow A shows the effect of reducing pressure from 2 atm to 0.05 atm, at 15 °C. The compound passes directly from a solid to a gas: it sublimes.

Describe what happens when the temperature is raised from 13 °C to 87 °C at a constant pressure of 1.25 atm?

Arrow B shows the effect of increasing the temperature from 13 °C to 87 °C at \( P = 1.25 \text{ atm} \). The substance passes from solid to liquid: it melts.

Which is more dense, the solid or the liquid? Explain your reasoning.

The solid is more dense. The gradient of the solid/liquid equilibrium line is positive. If the pressure is increased when the compound is on the solid/liquid equilibrium line moves the compound into the solid region. Hence, the solid is more stable than the liquid under increased pressure so it must occupy less volume. It must therefore be more dense than the liquid.
Carbon has a number of allotropes, the two major ones being graphite and diamond. What are allotropes?

**Allotropes are different molecular forms of the same element.**

Give an example of a pair of allotropes not involving carbon.

**Examples include:**
- white and red phosphorus
- graphite and diamond
- O\(_2\) and O\(_3\)

The phase diagram of carbon shows that diamond is not the stable allotrope under normal conditions. Why then does diamond exist under normal conditions?

Although graphite is the thermodynamically stable allotrope under normal conditions, there is a large activation energy for the diamond \(\rightarrow\) graphite conversion.

The conversion requires considerable rearrangement of the atoms and the bonds. As the covalent lattice network of diamond is very strong, disturbing it requires more energy than is available under normal conditions.

- Complete the following table.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Oxidation state of transition metal</th>
<th>Coordination number of transition metal</th>
<th>Number of d-electrons in metal in complex ion</th>
<th>Species formed upon dissolving in water</th>
</tr>
</thead>
<tbody>
<tr>
<td>(K_2[Ni(CN)_4])</td>
<td>+2</td>
<td>4</td>
<td>8</td>
<td>(K^+(aq), [Ni(CN)_4]^{2-}(aq))</td>
</tr>
<tr>
<td>[Cr(NH(_3)_3]Cl]Cl(_2)</td>
<td>+3</td>
<td>6</td>
<td>3</td>
<td>([Cr(NH_3)_3]^{2+}(aq), Cl^-(aq))</td>
</tr>
<tr>
<td>[Co(en)(_3)]Br(_3)</td>
<td>+3</td>
<td>6</td>
<td>6</td>
<td>([Co(en)_3]^{3+}(aq), Br^- (aq))</td>
</tr>
</tbody>
</table>

en = ethylenediamine = NH\(_2\)CH\(_2\)CH\(_2\)NH\(_2\)
Many elemental metals crystallise in one of three cubic forms, either with a face-centred cubic, a body-centred cubic or a simple cubic unit cell. Explain the main differences and similarities between these different crystalline forms.

All three are based on a cubic unit cell:

- The simple cubic form has atoms on each corner so that the atoms are stacked directly one on top of the other. As the 8 atoms are shared with eight other cubes, each contributes 1/8 to the cell so that the cell contains $8 \times 1/8 = 1$ atom. The atoms touch along the edges of the cube.
- The body centred cubic form has an additional atom in the cube centre, giving a total of 2 atoms in the cell. The atoms touch along the cube diagonal.
- The face centred cubic form has atoms on each corner and atoms at the centre of each face (with no atom at the centre of the cube). The atoms on the face centres are shared with two other cubes and so contribute 1/2 to the cell. The cell contains $8 \times 1/8$ (corner) + $6 \times 1/2$ (face) = 4. The atoms touch along the face diagonals.
- The face centred cubic form is the only close packed structure and is the most dense.
- In a face centred cubic structure, 74% of the space is occupied. In a body centred cubic, 68% is occupied. In a simple cubic structure, 52% is occupied.

Teeth are made from hydroxyapatite, $\text{Ca}_5(\text{PO}_4)_3\text{OH}$. Why does an acidic medium promote tooth decay? Use chemical equations where appropriate.

Hydroxyapatite dissolves in water according to the equation:

$$\text{Ca}_5(\text{PO}_4)_3\text{OH}(s) \rightleftharpoons 5\text{Ca}^{2+}(aq) + 3\text{PO}_4^{3-}(aq) + \text{OH}^-(aq)$$

In a non-acidic medium, the equilibrium lies to the left. In acidic media, $\text{H}^+$ reacts with both $\text{PO}_4^{3-}$ and $\text{OH}^-$ to form the conjugate acids ($\text{HPO}_4^{2-}$ and $\text{H}_2\text{O}$, respectively) and this shifts the equilibrium to the right and the tooth dissolves.

How does the fluoridation of drinking water aid the prevention of tooth decay?

Fluoridation can replace $\text{OH}^-$ forming $\text{Ca}_5(\text{PO}_4)_3\text{F}(s)$. This is less soluble than hydroxyapatite - it does not react with $\text{H}^+$ to the same extent as $\text{OH}^-$. 