Chemguide – answers

METALLIC BONDING

1. a) K: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
   Ca: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
   Sc: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$

b) In solid potassium, the $4s^1$ electrons from all the potassium atoms overlap to form a huge system of delocalised molecular orbitals which extend over the whole piece of metal. Delocalisation means that the electrons are no longer tied to particular atoms. The attractions between the delocalised electrons and the potassium nuclei (offset by the screening effect of the inner electrons) hold the structure together.

You could also describe this in terms of the $4s^1$ electrons forming a "sea of electrons", no longer tied to particular atoms. Once these electrons have been taken away from a particular atom, you are essentially left with an array of potassium ions surrounded by this sea of electrons. Attractions between the ions and the sea hold the structure together.

Personally, I prefer the more accurate first version!

c) Because you have to supply more energy to break the bonds (shown by the higher melting and boiling points), the strength of the metallic bonds increases from potassium to calcium to scandium.

d) The strength of the metallic bond will depend on the attractions between the delocalised electrons and the nuclei of the atoms that they surround.

In potassium, one electron per atom is delocalised; in calcium, two electrons per atom are delocalised; and in scandium there are three (including the 3d electron). So the electron "sea" gets increasingly more negative as you go from potassium to calcium to scandium.

At the same time, the number of protons in the nuclei is also increasing – 19 in potassium; 20 in calcium; and 21 in scandium.

The delocalised electrons are screened from the protons by exactly the same 18 inner electrons in each of these atoms – the $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ electrons.

Allowing for this screening, there will be a 1+ pull from the nucleus in potassium; 2+ in calcium; and 3+ in scandium. So the attractions increase because you not only have an increasingly more negative "sea", but a greater positive pull from the nuclei of the atoms. (You could also explain this in terms of the charges on the ions formed if you are using that model: 1+, 2+ and 3+.)

You might also have commented that the atoms will be getting smaller as you go across the period, and so the distance from the nuclei to the delocalised electrons gets smaller. That will increase the attractions.

There will also be a slight effect because the arrangement of the atoms in potassium is different from that in calcium and scandium. I wouldn't expect you to know that.