# AP® Chemistry
# 2002 Sample Student Responses



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6. Use the principles of atomic structure and/or chemical bonding to explain each of the following. In each part, your answer must include references to both substances.

(a) The atomic radius of Li is larger than that of Be.

(b) The second ionization energy of K is greater than the second ionization energy of Ca .

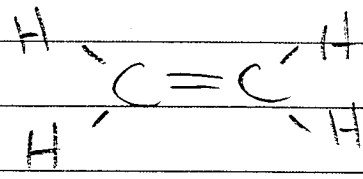
(c) The carbon-to-carbon bond energy in $C_2H_4$ is greater than it is in $C_2H_6$ .

(d) The boiling point of $Cl_2$ is lower than the boiling point of $Br_2$ .

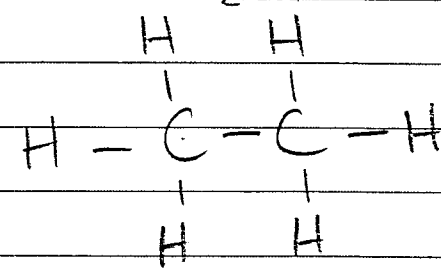
a) Li has a larger atomic radius because it has fewer protons pulling on the same number of shells. The extra proton in Be pulls the 2s subshell in closer decreasing the radius.

b) The second ionization energy is the amount of energy needed to remove the second-outermost electron from an atom. The second outermost electron in Ca is in the 4s subshell. The second outermost electron in K is in the 3p subshell, much closer to the nucleus than the 4s subshell and therefore harder to remove increasing the second ionization energy.

c) The Lewis structure for $C_2H_4$ is:



The Lewis structure for $C_2H_6$ is:



In $C_2H_4$ the C to C bond is a double bond while the C to C bond in $C_2H_6$ is only a single bond. Double bonds are stronger and more stable than single bonds because they are a sigma ($\sigma$) and a pi ($\pi$) bond instead of just a sigma. Stronger bonds have greater bond energies because they are harder to break and release more energy when broken.

ADDITIONAL PAGE FOR ANSWERING QUESTION 6.

d) $Br_2$ has stronger London dispersion forces than $Cl_2$ because it has more electrons. Stronger intermolecular forces makes it harder to put the molecules into vapor state. More energy must be added to $Br_2$ to break the intermolecular bonds than must be added to $Cl_2$ so $Cl_2$ does not have to get as hot before it boils (a substance boils when its vapor pressure equals the atmospheric pressure).

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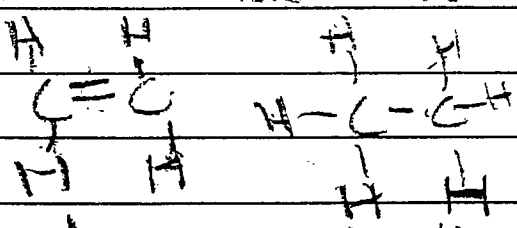
(d) The boiling point of $Cl_2$ is lower than the boiling point of $Br_2$ .

a) The atomic radius of Li is larger because Li has less protons in the nucleus than Be. The greater positive force in the Be nucleus pulls the electrons closer to the center of the atom, decreasing the nucleus.

b) K has only one valence electron while Ca has two. The second ionization energy is greater for K because the second electron is located in a full energy level closer to the nucleus, so the force keeping it with the atom is greater. Ca's second electron is still in the valence shell and there is not as much attraction between it and the nucleus.

c) 

The bond energy in the C-C bond in $C_2H_4$ is greater because it is a double bond, while the one in $C_2H_6$ is only a single bond which has less energy

d) $Cl_2$ is a gas at room temperature while $Br_2$ is a liquid. The $Br_2$ atom is larger than the $Cl_2$ atom so it has greater london dispersion forces. This $Br_2$ requires more energy to overcome these forces so therefore the boiling point is higher.

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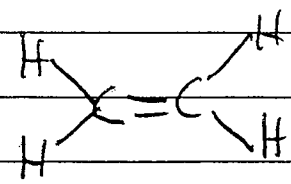
(d) The boiling point of $Cl_2$ is lower than the boiling point of $Br_2$ .

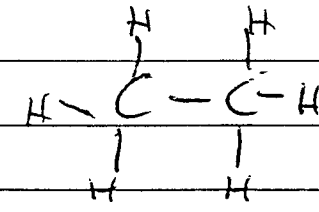
a) The atomic radius of Li is larger than Be due to the number of protons in the nucleus. There are more protons in the nucleus of Be than there are in Li, but there is no additional electron level added. These protons will exhibit a larger pull on the electrons of Be thus making it smaller.

b) The ionization energy is the energy that is required to remove the outermost electron. Removing the first $e^-$ from K brings it to a stable state. The outer shell has $8e^-$. It requires a massive amount of energy to remove an electron from a full shell versus the energy to remove one $e^-$ from a non-full shell. Removing two electrons from Ca brings it to a full outer shell but no further.

c) Structure of $C_2H_4$:



Structure of $C_2H_6$:



The Carbon to carbon bond in $C_2H_4$ is greater than in $C_2H_6$ due to the fact that $C_2H_4$ has a double bond in the C-C bond. $C_2H_6$ does not have a double bond.

d) The boiling point of $Cl_2$ is lower than the boiling point of $Br_2$ due to the forces inside the atom. The London dispersion forces on $Cl_2$ are greater than on $Br_2$. The $Cl_2$ is also more electronegative than $Br_2$. Both of these factors contribute to the lower boiling point.

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