



## AP<sup>®</sup> Chemistry 2003 Sample Student Responses Form B

**The materials included in these files are intended for use by AP teachers for course and exam preparation; permission for any other use must be sought from the Advanced Placement Program<sup>®</sup>. Teachers may reproduce them, in whole or in part, in limited quantities for noncommercial, face-to-face teaching purposes. This permission does not apply to any third-party copyrights contained herein. This material may not be mass distributed, electronically or otherwise. These materials and any copies made of them may not be resold, and the copyright notices must be retained as they appear here.**

These materials were produced by Educational Testing Service<sup>®</sup> (ETS<sup>®</sup>), which develops and administers the examinations of the Advanced Placement Program for the College Board. The College Board and Educational Testing Service (ETS) are dedicated to the principle of equal opportunity, and their programs, services, and employment policies are guided by that principle.

The College Board is a national nonprofit membership association whose mission is to prepare, inspire, and connect students to college and opportunity. Founded in 1900, the association is composed of more than 4,300 schools, colleges, universities, and other educational organizations. Each year, the College Board serves over three million students and their parents, 22,000 high schools, and 3,500 colleges through major programs and services in college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT<sup>®</sup>, the PSAT/NMSQT<sup>®</sup>, and the Advanced Placement Program<sup>®</sup> (AP<sup>®</sup>). The College Board is committed to the principles of equity and excellence, and that commitment is embodied in all of its programs, services, activities, and concerns.

For further information, visit [www.collegeboard.com](http://www.collegeboard.com)

Copyright © 2003 College Entrance Examination Board. All rights reserved. College Board, Advanced Placement Program, AP, AP Vertical Teams, APCD, Pacesetter, Pre-AP, SAT, Student Search Service, and the acorn logo are registered trademarks of the College Entrance Examination Board. AP Central is a trademark owned by the College Entrance Examination Board. PSAT/NMSQT is a registered trademark jointly owned by the College Entrance Examination Board and the National Merit Scholarship Corporation. Educational Testing Service and ETS are registered trademarks of Educational Testing Service. Other products and services may be trademarks of their respective owners.

For the College Board's online home for AP professionals, visit AP Central at [apcentral.collegeboard.com](http://apcentral.collegeboard.com).

Answer EITHER Question 7 below OR Question 8 printed on page 26. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 15 percent.

7. Account for the following observations using principles of atomic structure and/or chemical bonding. In each part, your answer must include specific information about both substances.
- (a) The  $\text{Ca}^{2+}$  and  $\text{Cl}^-$  ions are isoelectronic, but their radii are not the same. Which ion has the larger radius? Explain.
  - (b) Carbon and lead are in the same group of elements, but carbon is classified as a nonmetal and lead is classified as a metal.
  - (c) Compounds containing Kr have been synthesized, but there are no known compounds that contain He.
  - (d) The first ionization energy of Be is  $900 \text{ kJ mol}^{-1}$ , but the first ionization energy of B is  $800 \text{ kJ mol}^{-1}$ .

A) Both ~~atoms~~ <sup>ions</sup> have the same number of electrons. Therefore, both there is identical shielding in both ions. However, the sizes are not the same, as the values for  $Z_{\text{effective}}$ , the amount of attraction ~~atoms~~ between the nucleus and electrons, is different.  $\text{Ca}^{2+}$  has 20 protons in the nucleus, whilst  $\text{Cl}^-$  has 17.

For this reason,  $\text{Ca}^{2+}$  is a smaller ion. It has a smaller ionic radius than  $\text{Cl}^-$ . This is because the increased positive charge in the nucleus of  $\text{Ca}^{2+}$  attracts the electrons more strongly than in the  $\text{Cl}^-$  ion.  $Z_{\text{effective}}$  is proportional to the amount of protons in the nucleus, and since  $Z_{\text{effective}}$  is greater in  $\text{Ca}^{2+}$ , and than in  $\text{Cl}^-$ , and since shielding is identical, the  $\text{Ca}^{2+}$  is a smaller ion.

B) Carbon is in period 2 of the periodic table. Lead is in period 6 of the periodic table. Both are in the same group (IV). However, lead is a metal because it has a lower  $Z_{\text{effective}}$  than carbon. The added electron shells as you move down a group increase shielding of the  $Z_{\text{effective}}$ . Also, as shells are added, the size of the atoms increase. Thus, the outer electrons are able to be removed easily in Pb. In C, however, electrons are close to the nucleus, and they feel a larger  $Z_{\text{effective}}$ . Pb is a metal as the low  $Z_{\text{effective}}$  enables it some valence electrons to be released/removed.

GO ON TO THE NEXT PAGE.

## ADDITIONAL PAGE FOR ANSWERING QUESTION 7.

This allows electricity to be conducted. In C, electrons must be added, as the C will not readily give up its electrons.

C) Kr is in period 4, whilst He is in period 1. Kr compounds have been synthesized because Kr atoms contain empty 3d orbitals. Although both atoms have completely filled s and p orbitals, Kr has empty 3d orbitals which can be used to form bonds. Bonding electrons can be placed in the empty 3d orbitals, allowing bonds to be formed. He, however, has no such empty d orbital. Thus, bonds cannot be formed, due to the lack of space for bonding electrons. Thus, Kr can form molecules, whilst He is a lone atom which is stable.

D) Be has a higher first ionization energy than B. Be has a full 2s orbital. B has a full 2s orbital, and one electron ~~of~~ in the 2p orbitals. The first ionization energy deals with removing the electron with the greatest energy. In B, the full 2s orbital shields the electron in the 2p orbital. This electron thus feels a smaller  $Z_{\text{effective}}$ , and feels less attracted to the nucleus. This allows the electron to be pulled off more easily. Thus, ionization energy for this electron is lower than in Be, where no such extra shielding exists. In B, the shielding is greater than the change in  $Z_{\text{effective}}$  from Be to B.

GO ON TO THE NEXT PAGE.

Answer EITHER Question 7 below OR Question 8 printed on page 26. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 15 percent.

7. Account for the following observations using principles of atomic structure and/or chemical bonding. In each part, your answer must include specific information about both substances.
- (a) The  $\text{Ca}^{2+}$  and  $\text{Cl}^-$  ions are isoelectronic, but their radii are not the same. Which ion has the larger radius? Explain.
  - (b) Carbon and lead are in the same group of elements, but carbon is classified as a nonmetal and lead is classified as a metal.
  - (c) Compounds containing Kr have been synthesized, but there are no known compounds that contain He.
  - (d) The first ionization energy of Be is  $900 \text{ kJ mol}^{-1}$ , but the first ionization energy of B is  $800 \text{ kJ mol}^{-1}$ .

A)  $\text{Cl}^-$  has a larger radius than  $\text{Ca}^{2+}$ . This is because, in  $\text{Ca}^{2+}$ , the effective nuclear charge is increased with the loss of 2 valence electrons, this draws the remaining electrons closer to the nucleus, decreasing the radius. In  $\text{Cl}^-$  the addition of one outer electron lowers the effective nuclear charge, allowing the electrons to spread out more, increasing the radius.

B) Carbon is classified a non-metal because it tends to form covalent rather than ionic bonds, carbon also does not show the characteristics of metals such as being malleable or conducting electricity well. ~~Lead~~ Lead tends to form ionic bonds and has variable oxidation states, these are characteristics of other transition metals so lead is classified as a metal.

**GO ON TO THE NEXT PAGE.**

## ADDITIONAL PAGE FOR ANSWERING QUESTION 7.

C) While He and Kr are both noble gases, the relative sizes of the two atoms are very different. Helium is very small and has a full valence shell of 2, which pairs with its 2 protons in the nucleus. ~~Since~~ Since the distance between the electrons and nucleus is so small and the effective nuclear charge so strong, it is very difficult to pull an electron off a Helium atom to allow it to react. Krypton is much larger than Helium so therefore it's much easier to pull electrons off the atom than it is to do so with Helium.

D) Since Be and B have different nuclear charges and numbers of electrons, the effective nuclear charge in a Be is greater than that of a B atom. This makes it more difficult to separate electrons from Be atom than a B atom, thus Be has a higher first ionization energy than B.

GO ON TO THE NEXT PAGE.