AP® CHEMISTRY
2009 SCORING GUIDELINES

Question 6 (8 points)

Answer the following questions related to sulfur and one of its compounds.

(a) Consider the two chemical species S and S^{2-}.

(i) Write the electron configuration (e.g., $1s^2\ 2s^2$ . . .) of each species.

S: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ S^{2-}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ Note: Replacement of $1s^2\ 2s^2\ 2p^6$ by [Ne] is acceptable.	One point is earned for the correct configuration for S. One point is earned for the correct configuration for S^{2-}.

(ii) Explain why the radius of the S^{2-} ion is larger than the radius of the S atom.

The nuclear charge is the same for both species, but the eight valence electrons in the sulfide ion experience a greater amount of electron-electron repulsion than do the six valence electrons in the neutral sulfur atom. This extra repulsion in the sulfide ion increases the average distance between the valence electrons, so the electron cloud around the sulfide ion has the greater radius.	One point is earned for a correct explanation.

(iii) Which of the two species would be attracted into a magnetic field? Explain.

The sulfur atom would be attracted into a magnetic field. Sulfur has two unpaired *p* electrons, which results in a net magnetic moment for the atom. This net magnetic moment would interact with an external magnetic field, causing a net attraction into the field. The sulfide ion would not be attracted into a magnetic field because all the electrons in the species are paired, meaning that their individual magnetic moments would cancel each other.	One point is earned for the correct answer with a correct explanation.

(b) The S^{2-} ion is isoelectronic with the Ar atom. From which species, S^{2-} or Ar, is it easier to remove an electron? Explain.

It requires less energy to remove an electron from a sulfide ion than from an argon atom. A valence electron in the sulfide ion is less attracted to the nucleus (charge +16) than is a valence electron in the argon atom (charge +18).	One point is earned for the correct answer with a correct explanation.

Question 6 (continued)

(c) In the H_2S molecule, the H–S–H bond angle is close to 90°. On the basis of this information, which atomic orbitals of the S atom are involved in bonding with the H atoms?

The atomic orbitals involved in bonding with the H atoms in H_2S are p (specifically, $3p$) orbitals. The three p orbitals are mutually perpendicular (i.e., at 90°) to one another.	One point is earned for the correct answer.

(d) Two types of intermolecular forces present in liquid H_2S are London (dispersion) forces and dipole-dipole forces.

(i) Compare the strength of the London (dispersion) forces in liquid H_2S to the strength of the London (dispersion) forces in liquid H_2O. Explain.

The strength of the London forces in liquid H_2S is greater than that of the London forces in liquid H_2O. The electron cloud of H_2S has more electrons and is thus more polarizable than the electron cloud of the H_2O molecule.	One point is earned for the correct answer with a correct explanation.

(ii) Compare the strength of the dipole-dipole forces in liquid H_2S to the strength of the dipole-dipole forces in liquid H_2O. Explain.

The strength of the dipole-dipole forces in liquid H_2S is weaker than that of the dipole-dipole forces in liquid H_2O. The net dipole moment of the H_2S molecule is less than that of the H_2O molecule. This results from the lesser polarity of the H–S bond compared with that of the H–O bond (S is less electronegative than O).	One point is earned for the correct answer with a correct explanation.