At 298 K and 1 atm, the standard state of \( \text{Br}_2 \) is a liquid, whereas the standard state of \( \text{I}_2 \) is a solid. The enthalpy changes for the formation of \( \text{Br}_2(g) \) and \( \text{I}_2(g) \) from these elemental forms at 298 K and 1 atm are given in the table above.

(a) Explain why \( \Delta H^\circ \) for the formation of \( \text{I}_2(g) \) from \( \text{I}_2(s) \) is larger than \( \Delta H^\circ \) for the formation of \( \text{Br}_2(g) \) from \( \text{Br}_2(l) \). In your explanation identify the type of particle interactions involved and a reason for the difference in magnitude of those interactions.

Two reasons may be given. The first reason is that London dispersion forces, the only intermolecular forces involved for both of these nonpolar molecules, will be stronger in \( \text{I}_2 \) because of its greater number of electrons and larger size. The second reason is that since \( \Delta H \) of sublimation is approximately \( \Delta H \) of fusion plus \( \Delta H \) of vaporization, \( \text{I}_2(g) \) should have a larger \( \Delta H^\circ \) of formation since it involves sublimation, whereas \( \text{Br}_2(g) \) formation involves only vaporization.

(b) Predict which of the two processes shown in the table has the greater change in entropy. Justify your prediction.

\( \text{I}_2(s) \rightarrow \text{I}_2(g) \) should have the greater change in entropy. The sublimation of \( \text{I}_2 \) may be thought of as a combination of fusion and vaporization. The conversion from solid to liquid would involve an increase in entropy, as would the conversion from liquid to gas. \( \text{Br}_2 \) is only undergoing the liquid to gas conversion and so will undergo a smaller entropy increase.
(c) I$_2$(s) and Br$_2$(l) can react to form the compound IBr(l). Predict which would have the greater molar enthalpy of vaporization, IBr(l) or Br$_2$(l). Justify your prediction.

IBr(l). Two reasons may be given. First, IBr is polar, and dipole-dipole forces would tend to increase the enthalpy of vaporization. Second, IBr should have stronger London dispersion forces because of the greater number of electrons in the larger IBr molecule.

1 point is earned for the correct choice with either or both of the acceptable reasons.

An experiment is performed to compare the solubilities of I$_2$(s) in different solvents, water and hexane (C$_6$H$_{14}$). A student adds 2 mL of H$_2$O and 2 mL of C$_6$H$_{14}$ to a test tube. Because H$_2$O and C$_6$H$_{14}$ are immiscible, two layers are observed in the test tube. The student drops a small, purple crystal of I$_2$(s) into the test tube, which is then corked and inverted several times. The C$_6$H$_{14}$ layer becomes light purple, while the H$_2$O layer remains virtually colorless.

(d) Explain why the hexane layer is light purple while the water layer is virtually colorless. Your explanation should reference the relative strengths of interactions between molecules of I$_2$ and the solvents H$_2$O and C$_6$H$_{14}$, and the reasons for the differences.

The hexane layer is purple because most of the I$_2$ is dissolved in it. The entrance of the I$_2$ into water requires disruption of the hydrogen bonds in water, which are much stronger than the London dispersion forces in hexane. Meanwhile, the London dispersion forces between I$_2$ and hexane would be stronger than the London dispersion forces between I$_2$ and water. (Water and I$_2$ can also interact through a dipole-induced dipole force, but this attraction is insufficient to overcome the other differences noted above.)

1 point is earned for recognizing from the experimental observations that the iodine dissolved in the hexane.
1 point is earned for a correct explanation referencing the differences between water and hexane in their interactions with I$_2$.

(e) The student then adds a small crystal of KI(s) to the test tube. The test tube is corked and inverted several times. The I$^-$ ion reacts with I$_2$ to form the I$_3^-$ ion, a linear species.

(i) In the box below, draw the complete Lewis electron-dot diagram for the I$_3^-$ ion.

\[
\text{[I}^{\text{-}}\text{-}[\text{I}^{\text{-}}\text{-}[\text{I}^{\text{-}}]]^{-}
\]

1 point is earned for a correct Lewis diagram.
Question 5 (continued)

(ii) In which layer, water or hexane, would the concentration of $I_3^-$ be higher? Explain.

$I_3^-$ would be more soluble in water because of the ion-dipole interactions that would occur between the ions and the polar water molecules. No such interactions are possible in the nonpolar hexane.  

1 point is earned for the correct choice and explanation.