AP® CHEMISTRY
2012 SCORING GUIDELINES

Question 5
(8 points)

Process	$\Delta H°$ (kJ/mol$_{rxn}$)
$Br_2(l) \rightarrow Br_2(g)$	30.91
$I_2(s) \rightarrow I_2(g)$	62.44

At 298 K and 1 atm, the standard state of Br_2 is a liquid, whereas the standard state of I_2 is a solid. The enthalpy changes for the formation of $Br_2(g)$ and $I_2(g)$ from these elemental forms at 298 K and 1 atm are given in the table above.

(a) Explain why $\Delta H°$ for the formation of $I_2(g)$ from $I_2(s)$ is larger than $\Delta H°$ for the formation of $Br_2(g)$ from $Br_2(l)$. 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 I_2 because of its greater number of electrons and larger size. The second reason is that since ΔH of sublimation is approximately ΔH of fusion plus ΔH of vaporization, $I_2(g)$ should have a larger $\Delta H°$ of formation since it involves sublimation, whereas $Br_2(g)$ formation involves only vaporization.	1 point is earned for identifying London dispersion forces. 1 point is earned for either of the following: explaining the reason for the greater LDFs in I_2 OR stating that the enthalpy change from solid to gas is greater than the enthalpy change from liquid to gas.

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

$I_2(s) \rightarrow I_2(g)$ should have the greater change in entropy. The sublimation of 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. Br_2 is only undergoing the liquid to gas conversion and so will undergo a smaller entropy increase.	1 point is earned for the correct choice with a correct explanation.

Question 5 (continued)

(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.

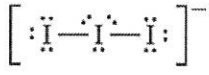
An experiment is performed to compare the solubilities of $I_2(s)$ in different solvents, water and hexane (C_6H_{14}). A student adds 2 mL of H_2O and 2 mL of C_6H_{14} to a test tube. Because H_2O and C_6H_{14} are immiscible, two layers are observed in the test tube. The student drops a small, purple crystal of $I_2(s)$ into the test tube, which is then corked and inverted several times. The C_6H_{14} layer becomes light purple, while the H_2O 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_2O and C_6H_{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.

	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.