

AP[®] CHEMISTRY
2012 SCORING GUIDELINES

Question 5
(8 points)

Process	ΔH° (kJ/mol _{rxn})
$\text{Br}_2(l) \rightarrow \text{Br}_2(g)$	30.91
$\text{I}_2(s) \rightarrow \text{I}_2(g)$	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 $\text{Br}_2(g)$ and $\text{I}_2(g)$ from these elemental forms at 298 K and 1 atm are given in the table above.

- (a) Explain why ΔH° for the formation of $\text{I}_2(g)$ from $\text{I}_2(s)$ is larger than ΔH° 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.

<p>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, $\text{I}_2(g)$ should have a larger ΔH° of formation since it involves sublimation, whereas $\text{Br}_2(g)$ formation involves only vaporization.</p>	<p>1 point is earned for identifying London dispersion forces.</p> <p>1 point is earned for either of the following: explaining the reason for the greater LDFs in I_2</p> <p>OR</p> <p>stating that the enthalpy change from solid to gas is greater than the enthalpy change from liquid to gas.</p>
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- (b) Predict which of the two processes shown in the table has the greater change in entropy. Justify your prediction.

<p>$\text{I}_2(s) \rightarrow \text{I}_2(g)$ 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.</p>	<p>1 point is earned for the correct choice with a correct explanation.</p>
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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.

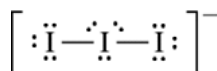
The hexane layer is purple because most of the I_2 is dissolved in it. The entrance of the I_2 into water requires disruption of the hydrogen bonds in water, which are much stronger than the London dispersion forces in hexane. Meanwhile, the London dispersion forces between I_2 and hexane would be stronger 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.

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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.