2018

AP CollegeBoard

# AP Chemistry

## Sample Student Responses and Scoring Commentary

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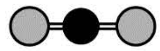
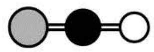
## Question 4

Sulfur atom =  Carbon atom =  Oxygen atom = 

| Compound | Molecular Structure | Boiling Point at 1 atm (K) |
|---|---|---|
| $CS_2$ |  | 319 |
| COS |  | 223 |

The table above gives the molecular structures and boiling points for the compounds $CS_2$ and COS.

(a) In terms of the types and relative strengths of all the intermolecular forces in each compound, explain why the boiling point of $CS_2(l)$ is higher than that of $COS(l)$.

| | |
|---|---|
| $CS_2$ has only London dispersion forces, while COS has London dispersion forces and dipole-dipole forces. | 1 point is earned for correctly identifying all of the intermolecular forces in **both** molecules. |
| The London dispersion forces in $CS_2$ are stronger than the combination of London dispersion forces and dipole-dipole forces in COS. | 1 point is earned for a valid explanation. |

(b) A 10.0 g sample of $CS_2(l)$ is put in an evacuated 5.0 L rigid container. The container is sealed and heated to 325 K, at which temperature all of the $CS_2(l)$ has vaporized. What is the pressure in the container once all of the $CS_2(l)$ has vaporized?

| | |
|---|---|
| $10.0 \text{ g } CS_2 \times \frac{1 \text{ mol } CS_2}{76.13 \text{ g } CS_2} = 0.131 \text{ mol } CS_2$ | 1 point is earned for the correct number of moles of $CS_2$. |
| $P = \frac{nRT}{V} = \frac{(0.131 \text{ mol})(0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1})(325 \text{ K})}{5.0 \text{ L}}$ $= 0.70 \text{ atm}$ | 1 point is earned for the correct calculation of pressure with appropriate units. |

Sulfur atom = (speckled circle) Carbon atom = (black circle) Oxygen atom = (white circle)

| | Compound | Molecular Structure | Boiling Point at 1 atm (K) |
|---|---|---|---|
| LDF np | $CS_2$ |  | 319 |
| LDF p DD | COS |  | 223 |

4. The table above gives the molecular structures and boiling points for the compounds $CS_2$ and COS.

(a) In terms of the types and relative strengths of all the intermolecular forces in each compound, explain why the boiling point of $CS_2(l)$ is higher than that of $COS(l)$.

(b) A 10.0 g sample of $CS_2(l)$ is put in an evacuated 5.0 L rigid container. The container is sealed and heated to 325 K, at which temperature all of the $CS_2(l)$ has vaporized. What is the pressure in the container once all of the $CS_2(l)$ has vaporized?

4. a) $CS_2(l)$ boiling point is higher than that of COS(l) because $CS_2$ is nonpolar with london dispersion forces that is stronger than the polar molecule COS's london dispersion forces and dipole-dipole IMFs. Since $CS_2$'s london dispersion forces are stronger than the london dispersion forces and dipole-dipole of the COS molecule, the boiling point of $CS_2$ would be greater than COS since more energy would need to be put in to boil $CS_2$ since it has stronger IMFs.

b) $\frac{10.0\text{ g } CS_2}{1} \left| \frac{1\text{ mol } CS_2}{76.13\text{ g } CS_2} \right. = 0.131\text{ mol } CS_2$

$$P = \frac{nRT}{V} = \frac{(.131\text{ mol})(.08206\ \frac{\text{L atm}}{\text{mol K}})(325\text{ K})}{(5.0\text{ L})} = \boxed{.699\text{ atm}}$$



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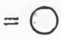
| Sulfur atom =  | Carbon atom =  | Oxygen atom =  |
|---|---|---|

| Compound | Molecular Structure | Boiling Point at 1 atm (K) |
|---|---|---|
| $CS_2$ |  | 319 |
| COS |  | 223 |

4. The table above gives the molecular structures and boiling points for the compounds $CS_2$ and COS.

(a) In terms of the types and relative strengths of all the intermolecular forces in each compound, explain why the boiling point of $CS_2(l)$ is higher than that of $COS(l)$.

(b) A 10.0 g sample of $CS_2(l)$ is put in an evacuated 5.0 L rigid container. The container is sealed and heated to 325 K, at which temperature all of the $CS_2(l)$ has vaporized. What is the pressure in the container once all of the $CS_2(l)$ has vaporized?

a. They both have London Dipersion forces howeve $CS_2$ is larger with more electrons which makes it more polarizable causing stronger IMFs & a higher boiling point.

b. $PV = nRT$

$P = \frac{nRT}{V}$

$n = \frac{10.0 g CS_2}{1} \cdot \frac{1 mol CS_2}{76.13 g CS_2}$

$n = 0.131 mol CS_2$

$P = \frac{(0.131 mol)(0.08206 L atm/mol K)(325 K)}{(5.0 L)}$

$P = 0.699 atm$



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H > LDS > dipole-dipole 4C 1 of 1

done

Sulfur atom = (shaded circle) Carbon atom = ● Oxygen atom = ○

| Compound | Molecular Structure | Boiling Point at 1 atm (K) |
| --- | --- | --- |
| $CS_2$ |  | 319 |
| COS |  | 223 |

4. The table above gives the molecular structures and boiling points for the compounds $CS_2$ and COS.

(a) In terms of the types and relative strengths of all the intermolecular forces in each compound, explain why the boiling point of $CS_2(l)$ is higher than that of COS($l$).

(b) A 10.0 g sample of $CS_2(l)$ is put in an evacuated 5.0 L rigid container. The container is sealed and heated to 325 K, at which temperature all of the $CS_2(l)$ has vaporized. What is the pressure in the container once all of the $CS_2(l)$ has vaporized?

a) The boiling point is higher is $CS_2$ due to the strong covalent bonds. The boiling point most be higher to break the bonds. It is also high because of the London dispersion bond which also requires more energy to break the bond.

b) $PV = nRT$ $P = \frac{nRT}{V}$

given: $\frac{10 g\ CS_2 \mid 1 mol}{\mid 76 g\ CS_2} = .132 mol\ CS_2 = n$

volume = 5 L

Temp = 325 K

R constant = .08206 L atm mol⁻¹ K⁻¹

$P = \frac{(.132 mol\ CS_2)(.08206 L\ atm\ mol^{-1} K^{-1})(325 K)}{5 L}$

$P = \frac{3.509\ atm\ L}{5 L}$ $P = \boxed{.702\ atm}$

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## Question 4

**Overview**

In part (a) the students were required to explain the differences in boiling point between $CS_2$ and COS in terms of the relative strengths of the intermolecular forces in each compound. In this case, the substance with the higher boiling point only had London dispersion forces, while the other substance had both London dispersion forces and dipole-dipole interactions. (LO 5.11; SP 7.2).

Students were required to recognize that the London dispersion forces between molecules of $CS_2(l)$ were stronger than the combination of London dispersion and dipole-dipole forces in COS($l$). The London dispersion forces among molecules of $CS_2(l)$ are stronger because $CS_2$ has a larger, more polarizable electron cloud than COS. These stronger intermolecular forces increase the boiling point of the substance (LO 2.11; SP 6.2, 6.4).

In part (b) students were asked to use the ideal gas law to calculate the pressure of a gas in a closed container after all the substance had vaporized (LO 2.6; SP 2.2, 2.3). They were required to report the correct value with units that were consistent with the version of *R* used in the intermediate calculations.

**Sample: 4A**
**Score: 4**

In part (a) the response correctly identifies the intermolecular forces (IMF) for both $CS_2$ and COS, "$CS_2$ is nonpolar with london dispersion forces that is stronger than the polar molecule COS's london dispersion forces and dipole-dipole IMFs," and 1 point was earned. The response earned 1 point for including a valid explanation as to why the boiling point of $CS_2$ is higher than the boiling point of COS: "$CS_2$'s london dispersion forces are stronger than the london dispersion forces and dipole-dipole of the COS molecule, the boiling point of $CS_2$ would be greater than COS." In part (b) the response states the correct number of moles of $CS_2$, 0.131 mol, and thus earned 1 point. One point was earned because the pressure is correctly calculated, and work and units are shown.

**Sample: 4B**
**Score: 3**

In part (a) the response does not identify all of the intermolecular forces (IMFs) present in both substances. The response states, "They both have London Dipersion [*sic*] forces," but there is no mention of dipole-dipole interactions present between COS molecules. Hence, no point was earned. The response does have a valid explanation for why the boiling point of $CS_2$ is higher than the boiling point of COS, "$CS_2$ is larger with more electrons which makes it more polarizable causing stronger IMFs & a higher boiling point." Because only London dispersion forces (LDFs) were stated as the IMFs in $CS_2$, the "stronger IMFs" must be referring to LDFs. This earned 1 point. In part (b) the response earned 1 point for the correct number of moles of $CS_2$: 0.131 mol. The pressure is also correctly calculated, and work and units are shown. This earned an additional 1 point.

**Sample: 4C**
**Score: 2**

In part (a) the response indicates that bond strength is correlated with boiling point, "The boiling point is higher in $CS_2$ due to the strong covalent bonds. The boiling point must be higher to break the bonds." There is a reference to a "London dispersion bond," but it is not clearly stated as an intermolecular force (IMF). Also, there

## Question 4 (continued)

is no mention of the dipole-dipole forces in COS. Therefore this response did not earn the point for correctly identifying all of the IMFs in each substance; nor did it earn a point for a valid explanation for the higher boiling point of $CS_2$. In part (b) the response earned 1 point as it has the correct the number of moles of $CS_2$: 0.132 mol. The pressure is correctly calculated, and work and units are shown. This earned an additional 1 point.