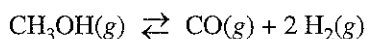


AP[®] CHEMISTRY
2011 SCORING GUIDELINES (Form B)

Question 2
(9 points)

An 8.55 mol sample of methanol, CH₃OH, is placed in a 15.0 L evacuated rigid tank and heated to 327°C. At that temperature, all of the methanol is vaporized and some of the methanol decomposes to form carbon monoxide gas and hydrogen gas, as represented in the equation below.



(a) The reaction mixture contains 6.30 mol of CO(g) at equilibrium at 327°C.

(i) Calculate the number of moles of H₂(g) in the tank.

$6.30 \text{ mol CO} \times \frac{2 \text{ mol H}_2}{1 \text{ mol CO}} = 12.6 \text{ mol H}_2$	1 point is earned for the correct number of moles.
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(ii) Calculate the number of grams of CH₃OH(g) remaining in the tank.

$6.30 \text{ mol CO} \times \frac{1 \text{ mol CH}_3\text{OH}}{1 \text{ mol CO}} = 6.30 \text{ mol CH}_3\text{OH reacted}$ $8.55 \text{ mol CH}_3\text{OH}_{\text{initial}} - 6.30 \text{ mol CH}_3\text{OH}_{\text{reacted}} = 2.25 \text{ mol CH}_3\text{OH}$ $2.25 \text{ mol} \times \frac{32.042 \text{ g}}{1 \text{ mol}} = 72.1 \text{ g}$	1 point is earned for the correct number of grams.
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(iii) Calculate the mole fraction of H₂(g) in the tank.

$\frac{12.6 \text{ mol H}_2}{2.25 \text{ mol CH}_3\text{OH} + 6.30 \text{ mol CO} + 12.6 \text{ mol H}_2}$ $= \frac{12.6}{21.15} = 0.596$	1 point is earned for the correct setup. 1 point is earned for the correct answer.
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(iv) Calculate the total pressure, in atm, in the tank at 327°C.

$PV = nRT \Rightarrow P = \frac{nRT}{V}$ $= \frac{(21.15 \text{ mol})(0.0821 \frac{\text{L atm}}{\text{mol K}})(600 \text{ K})}{15.0 \text{ L}}$ $= 69.5 \text{ atm}$	1 point is earned for the correct setup. 1 point is earned for the correct answer.
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Question 2 (continued)

(b) Consider the three gases in the tank at 327°C: CH₃OH(g), CO(g), and H₂(g).

(i) How do the average kinetic energies of the molecules of the gases compare? Explain.

The average kinetic energies are the same because all three gases are at the same temperature.

1 point is earned for the correct answer and explanation.

(ii) Which gas has the highest average molecular speed? Explain.

$KE = \frac{1}{2}mv^2$, so at a given temperature the molecules with the lowest mass have the highest average speed. Therefore the molecules in H₂ gas have the highest average molecular speed.

1 point is earned for the correct answer and explanation.

(c) The tank is cooled to 25°C, which is well below the boiling point of methanol. It is found that small amounts of H₂(g) and CO(g) have dissolved in the liquid CH₃OH. Which of the two gases would you expect to be more soluble in methanol at 25°C? Justify your answer.

The only attractive forces between molecules of H₂ and CH₃OH would be due to weak London dispersion forces (LDFs). In contrast, the LDFs are stronger between CO molecules and CH₃OH molecules because CO has more electrons than H₂. In addition CO is slightly polar; thus intermolecular dipole-dipole attractions can form between CO molecules and CH₃OH molecules. With stronger intermolecular interactions between molecules of CO and CH₃OH, CO would be expected to be more soluble in CH₃OH than H₂.

1 point is earned for the correct answer and justification.