AP® Chemistry
2002 Sample Student Responses
Form B

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Answer EITHER Question 2 below OR Question 3 printed on page 12. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 20 percent.

2. A rigid 8.20 L flask contains a mixture of 2.50 moles of H_2, 0.500 mole of O_2, and sufficient Ar so that the partial pressure of Ar in the flask is 2.00 atm. The temperature is 127°C.

   (a) Calculate the total pressure in the flask.

   (b) Calculate the mole fraction of H_2 in the flask.

   (c) Calculate the density (in g L^{-1}) of the mixture in the flask.

   The mixture in the flask is ignited by a spark, and the reaction represented below occurs until one of the reactants is entirely consumed.

$$2\,H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

   (d) Give the mole fraction of all species present in the flask at the end of the reaction.

a) $PV = nRT$

$P = \frac{nRT}{V} = \frac{(2.5 + 0.500) \times 0.08206 \times (127 + 273)}{8.2} = 12.01$ atm $(P_{H_2} + P_{O_2})$

12.01 atm + 2.00 atm = 14.01 atm

total pressure = 14.0 atm

b) moles Ar = $\frac{PV}{RT} = \frac{2 \times 8.2}{0.08206 \times 400}$ = .4996 mol

mole fraction H_2 = $\frac{\text{mol } H_2}{\text{total moles}} = \frac{2.50}{2.50 + 0.500 + .4996}$

mole fraction H_2 = .714

c) 8.20 L.

2.50 mol H_2 × 2.016 g/mol = 5.04 g

0.500 mol O_2 × 32.00 g/mol = 16.00 g

.4996 mol Ar × 39.95 g/mol = 19.96 g

total grams = 41.0 g

Density = $\frac{g}{L} = \frac{41.0}{8.20}$ = 5.00 g/L

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2.

d) $2H_2 + O_2 \rightarrow 2H_2O$

2.50 mol   0.500 mol

2 × mol O_2 < mol H_2, therefore O_2 is limiting reactant

$2H_2 + O_2 \rightarrow 2H_2O$

2.50-2x   0.500 − x   2x   , x = 0.500 mol

1.50 mol   0   1.00 mol

mol H_2O = 1.00 mol

mol H_2 = 1.50 mol

mol Ar = .4996 mol

mol fraction $H_2O = \frac{1.00}{1+1.5+.4996}$ = .333

mol fraction $H_2 = \frac{1.5}{1+1.5+.4996}$ = .500

mol fraction $Ar = \frac{.4996}{1+1.5+.4996}$ = .167

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   (d) Give the mole fraction of all species present in the flask at the end of the reaction.

V = 8.20 L   T = 127° C or 400.15 K

H_2 = 2.50 moles

O_2 = 0.500 moles

P_{Ar} = 2.00 atm

a) $PV = nRT$

$P = \frac{nRT}{V}$ $n = n_{H_2} + n_{O_2}$

$P_{H_2+O_2} = \frac{(2.50 \text{ moles } H_2 + 0.500 \text{ moles } O_2)(0.0821 \frac{L\,atm}{mol\,K})(400.15\,K)}{8.20\,L}$

= 12.019 L

$P_{Total} = P_{H_2} + P_{O_2} + P_{Ar}$

P_{total} = 12.019 atm 2 atm

= **14.0 atm**

b) $P_{H_2} = P_{total} \times X_{H_2}$

$\frac{n_{H_2}RT}{VP_{total}} = X_{H_2}$ $\frac{2.50 \text{ moles } H_2 (0.0821 \frac{L\,atm}{mol\,K})(400.15K)}{8.20L\,(14.019\,atm)} = X_{H_2}$

0.714 = X_{H_2}

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2.

c) $D = \frac{m}{V}$ $PV = nRT$ $n = \frac{PV}{RT}$ $n = \frac{m}{M}$

$D = \frac{P \cancel{V} M_{total}}{RT \cancel{V}}$ $m = \frac{PVM}{RT}$ $M_{total} = M_{H_2} + M_{O_2} + M_{Ar}$

$M_{H_2} = 2.016$

$M_{O_2} = 32.00$

$= \frac{(14.019 \text{ atm})(2.016 + 32.00 + 39.948 \text{ g/mol})}{(0.0821 \frac{\text{L atm}}{\text{mol K}})(400.15 \text{ K})}$ $M_{Ar} = 39.948$

$(atm)(\cancel{L})(\frac{g}{mol})(\frac{\cancel{mol K}}{\cancel{L atm}})(\frac{1}{\cancel{K}})$

$D = 258.81$

$= \frac{(14.019 \text{ atm})(2.016 + 32.00 + 39.948 \text{ g/mol})}{(0.0821 \frac{\text{L atm}}{\text{mol K}})(400.15 \text{ K})}$

$D = 31.6 \frac{g}{L}$

2.50 moles 0.500 moles → 1 mole

d) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

↑ limiting reagent

amount of H_2 consumed

$0.500 \text{ moles } O_2 \times \frac{2 \text{ moles } H_2O}{1 \text{ mole } O_2} \times \frac{2 \text{ moles } H_2}{2 \text{ moles } H_2O} = 1 \text{ mole } H_2$

⇒ 1.50 moles H_2 is left

since 1:1 ratio of H_2 and H_2O, only 1 mole of H_2O is produced when O_2 is consumed

$X_{O_2} = 0$

$X_{H_2} = \frac{1.50 \text{ moles } H_2}{2.50 \text{ moles total}} = 0.60\ H_2$

$X_{H_2O} = \frac{1 \text{ mole } H_2}{2.50 \text{ moles total}} = 0.40\ H_2O$

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