AP® Chemistry
2003 Sample Student Responses
Form B

2A 1

Answer EITHER Question 2 below OR Question 3 printed on page 14. 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. Answer the following questions that relate to chemical reactions.

   (a) Iron(III) oxide can be reduced with carbon monoxide according to the following equation.

   $$Fe_2O_3(s) + 3\,CO(g) \rightarrow 2\,Fe(s) + 3\,CO_2(g)$$

   A 16.2 L sample of $CO(g)$ at 1.50 atm and 200.°C is combined with 15.39 g of $Fe_2O_3(s)$.

   (i) How many moles of $CO(g)$ are available for the reaction?

   (ii) What is the limiting reactant for the reaction? Justify your answer with calculations.

   (iii) How many moles of $Fe(s)$ are formed in the reaction?

   (b) In a reaction vessel, 0.600 mol of $Ba(NO_3)_2(s)$ and 0.300 mol of $H_3PO_4(aq)$ are combined with deionized water to a final volume of 2.00 L. The reaction represented below occurs.

   $$3\,Ba(NO_3)_2(aq) + 2\,H_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6\,HNO_3(aq)$$

   (i) Calculate the mass of $Ba_3(PO_4)_2(s)$ formed.

   (ii) Calculate the pH of the resulting solution.

   (iii) What is the concentration, in mol L^{-1}, of the nitrate ion, $NO_3^-(aq)$, after the reaction reaches completion?

a) i) $PV = nRT \Rightarrow n = \frac{PV}{RT} = \frac{1.5(16.2)}{(0.0821)(473)} = 6.26 \times 10^{-1}$ mol

ii) number of moles of $Fe_2O_3 = n_{Fe_2O_3} = \frac{15.39}{(159.7)} = 9.637 \times 10^{-2}$ mol

1 mole of $Fe_2O_3 \longrightarrow$ 3 moles of CO

x mol of $Fe_2O_3 \longrightarrow$ 0.626 mol of CO

$\Rightarrow x = 0.209$ mol ; but we have only 9.637×10^{-2} mol of Fe_2O_3, which means that Fe_2O_3 is the limiting reagent.

~~iii)~~

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 2.

iii) 1 mole of Fe_2O_3 → 2 moles of Fe

9.637×10^{-2} mol of Fe_2O_3 → y moles of Fe

⇒ y = ~~2(9.63~~ $2(9.637 \times 10^{-2}) = 19.27 \times 10^{-2}$ mol

b) i) 3 moles of $Ba(NO_3)_2$ → 2 moles of H_3PO_4

0.6 moles of $Ba(NO_3)_2$ → x moles of H_3PO_4

⇒ $x = \frac{2(0.6)}{3} = 0.4$ moles of H_3PO_4 needed

but we have only 0.3 mol of H_3PO_4 ⇒ H_3PO_4 is the limiting reagent:

2 moles of H_3PO_4 → 1 mole of $Ba_3(PO_4)_2$

0.3 mol of H_3PO_4 → y moles of $Ba_3(PO_4)_2$

⇒ $y = \frac{0.3}{2} = 0.150$ mol of $Ba_3(PO_4)_2$ formed

= Mass of $Ba_3(PO_4)_2$ formed $= n_{Ba_3(PO_4)_2} \times M_{Ba_3(PO_4)_2}$

$= 0.150 \times 601$

$= 90.2$ g

ii) $HNO_3 \rightarrow H^+ + NO_3^-$ $[H^+] = [HNO_3] = \frac{0.900 \text{ mol}}{2.00 \text{ L}}$

⇒ $[H^+] = 0.450$ M ; $pH = -\log[H^+] = -\log(0.450) = 0.347$

iii) $[NO_3^-] = [H^+] = 0.450 \frac{mol}{L}$ from the HNO_3

but since $Ba(NO_3)_2$ is in excess:

$[Ba(NO_3)_2] = \frac{0.15}{2} = 0.0750$ M ⇒ $[NO_3^-] = 0.150$

⇒ Total $[NO_3^-] = 0.600$M

GO ON TO THE NEXT PAGE.

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   (iii) What is the concentration, in mol L^{-1}, of the nitrate ion, $NO_3^-(aq)$, after the reaction reaches completion?

(ai) $PV=nRT \Rightarrow (1.5)(16.2)=n\,(0.0821)(473) \Rightarrow n = 0.63$ moles of CO

$200°C \rightarrow 200+273 = 473\,K$

(aii) Molecular mass of Fe_2O_3 = 159.7 g/mol, 15.39g Fe_2O_3 is 15.39/159.7 = 0.096 moles

Fe_2O_3 is the limiting reacting is much less moles of it than CO

(aiii) $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ (0.19 moles) of Fe(s) are formed

	Fe_2O_3	$3CO$	$2Fe$	$3CO_2$	
Initially	.096	.63	0	0	→ in moles
Change	-.096	~	+.192	~	
End	0	~	.192	~	

GO ON TO THE NEXT PAGE.

(bi) $3Ba(NO_3)_2 + 2H_3PO_4 \Rightarrow Ba_3(PO_4)_2 + 6HNO_3$

Initially	.6	.3	0	0	→ in moles
Change	~	-.3	+.15	+.9	
End	~	0	.15	.9	

Molecular mass of $Ba_3(PO_4)_2$ = 601.94 g/mol

Mass of $Ba_3(PO_4)_2$ formed = 0.15 · 601.94 = 90.29 g ($\text{moles} = \frac{\text{grams}}{\text{molecular mass}}$)

(bii) 0.9 moles of HNO_3 had formed (found from the stoichemtric calculation in (bi))

HNO_3 is a strong acid so it completely disassociates into H^+ and NO_3^- ions in water

$[H^+] = \frac{\text{moles of solute}}{\text{L of solution}} = \frac{.9}{2} = 0.45\,M$

$pH = -\log[H^+] = -\log .45 = 0.35$

(biii) One moles of NO_3^- is formed from the disassication of HNO_3, 0.9 moles of HNO_3 had formed so 0.9 NO_3^- also formed

$[NO_3^-] = \frac{\text{moles of solute}}{\text{L of solution}} = \frac{.9}{2} = 0.45\,M$

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2C 1

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(ii) Calculate the pH of the resulting solution.

(iii) What is the concentration, in mol L^{-1}, of the nitrate ion, $NO_3^-(aq)$, after the reaction reaches completion?

2ai $Fe_2O_3(s) + 3\,CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$.

moles of CO(g) = ?

Given equation PV = nRT (P = Pressure, V = Volume, n = # of moles, R = gas constant, T = temperature (absolute)).

P = 1.5 atm.

V = 16.2 L

T = (200 + 273) K

R = 0.0821

⇒ 1.5(16.2) = n(0.0821)(200 + 273)

⇒ n = 0.6258 moles of CO(g) availiable.

ii. # moles of Fe_2O_3(s) availiable = n = m [(mass given)] / M [(molarmass)] = 15.39 / 159.7 = 0.0964 moles.

M of Fe_2O_3 = 159.7 g/mol

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$

1 : 3 : 2 : 3 (Reacting ratio (moles))

0.0964 moles (Given)

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 2.

⇒ # moles CO which react with 0.0964 moles Fe_2O_3 =

0.0964 × 3 = 0.2891 moles.

this value is less than the given value of CO(g) availiable (0.6258 moles) ⇒ Fe_2O_3(s) is the limiting reagent while CO(g) is in excess.

iii. By the reacting ratios. Fe_2O_3 : CO : Fe : CO_2 (moles)

1 3 2 3

0.0964 x moles of Fe(s) produced

⇒ x = 0.0964 × 2 = 0.1928 moles of Fe(s) formed.

2bi. Reacting ratio (moles) ⇒ $Ba(NO_3)_2$: H_3PO_4 : $Ba_3(PO_4)_2$: HNO_3

3 : 2 : 1 : 6

initial quatities (moles) ⇒ 0.6 0.3

For limiting reagent :– 0.6 x

⇒ $x = \frac{0.6 \cdot 2}{3} = 0.4$ > initial given H_3PO_4

⇒ H_3PO_4 is limiting

⇒ 0.3 x

⇒ x = # moles $Ba_3(PO_4)_2$ = 0.3/2 = 0.15 moles.

Molar mass of $Ba_3(PO_4)_2$ = 191 g/mol

⇒ mass of $Ba_3(PO_4)_2$ = 0.15 moles · $\frac{191}{1\,mol}$ = 28.6 g of $Ba_3(PO_4)_2$ formed.

ii. By reacting ratios # moles HNO_3 formed = (0.3 · 6)/2 = 0.9 moles

HNO_3 dissosiates completely into H^+ and NO_3^-

pH = – Log [H^+] , [H^+] = $\frac{0.9\ moles}{2L}$ = 0.45 M ⇒ pH = – log 0.45.

iii HNO_3 dissociates completely, so [H^+] = [NO_3^-] = [HNO_3] = $\frac{0.9\ moles}{2L}$ = 0.45 M.

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