



AP[®] Chemistry 2003 Sample Student Responses Form B

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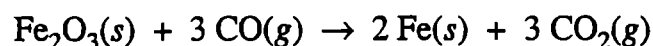
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2A₁

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.

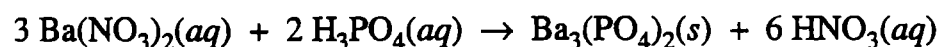
(a) Iron(III) oxide can be reduced with carbon monoxide according to the following equation.



A 16.2 L sample of $\text{CO}(g)$ at 1.50 atm and $200.^\circ\text{C}$ is combined with 15.39 g of $\text{Fe}_2\text{O}_3(s)$.

- How many moles of $\text{CO}(g)$ are available for the reaction?
- What is the limiting reactant for the reaction? Justify your answer with calculations.
- How many moles of $\text{Fe}(s)$ are formed in the reaction?

(b) In a reaction vessel, 0.600 mol of $\text{Ba}(\text{NO}_3)_2(s)$ and 0.300 mol of $\text{H}_3\text{PO}_4(aq)$ are combined with deionized water to a final volume of 2.00 L. The reaction represented below occurs.



- Calculate the mass of $\text{Ba}_3(\text{PO}_4)_2(s)$ formed.
- Calculate the pH of the resulting solution.
- What is the concentration, in mol L^{-1} , of the nitrate ion, $\text{NO}_3^-(aq)$, after the reaction reaches completion?

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

$$\text{ ii) } \text{Number of moles of } \text{Fe}_2\text{O}_3 = n_{\text{Fe}_2\text{O}_3} = \frac{15.39}{(159.7)} = 9.637 \times 10^{-2} \text{ mol}$$

1 mole of $\text{Fe}_2\text{O}_3 \longrightarrow 3$ moles of CO

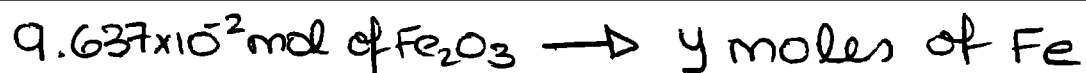
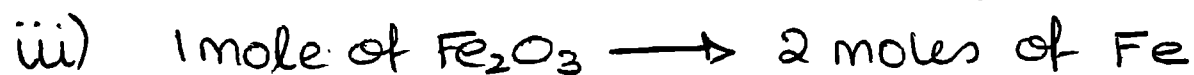
x mol of $\text{Fe}_2\text{O}_3 \longrightarrow 0.626$ mol of CO

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

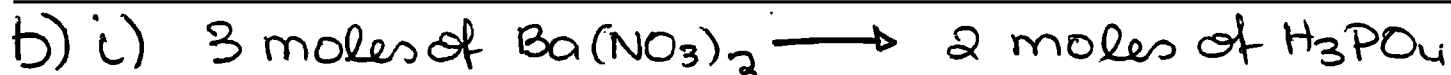
iii)

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2.

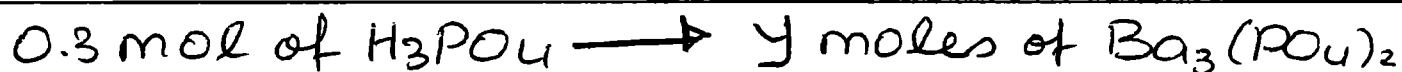


$$\Rightarrow y = \cancel{2(9.637)} \quad 2(9.637 \times 10^{-2}) = 19.27 \times 10^{-2} \text{ mol}$$



$$\Rightarrow x = \frac{2(0.6)}{3} = 0.4 \text{ moles of } \text{H}_3\text{PO}_4 \text{ needed}$$

but we have only 0.3 mol of $\text{H}_3\text{PO}_4 \Rightarrow \text{H}_3\text{PO}_4$ is the limiting reagent:

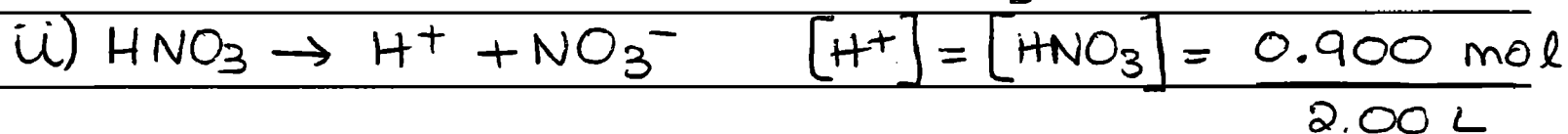


$$\Rightarrow y = \frac{0.3}{2} = 0.150 \text{ mol of } \text{Ba}_3(\text{PO}_4)_2 \text{ formed}$$

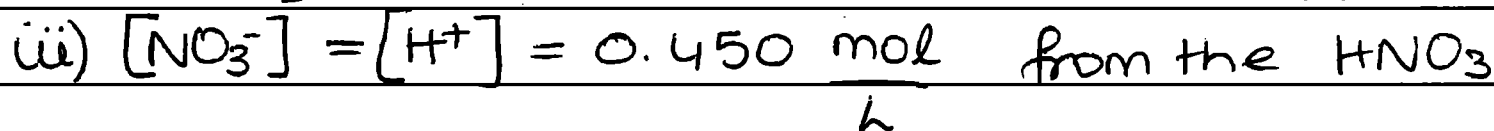
$$= \text{mass of } \text{Ba}_3(\text{PO}_4)_2 \text{ formed} = n_{\text{Ba}_3(\text{PO}_4)_2} \times M_{\text{Ba}_3(\text{PO}_4)_2}$$

$$= 0.150 \times 601$$

$$= 90.2 \text{ g}$$



$$\Rightarrow [\text{H}^+] = 0.450 \text{ M} ; \text{pH} = -\log[\text{H}^+] = -\log(0.450) = 0.347$$



but since $\text{Ba}(\text{NO}_3)_2$ is in excess:

$$[\text{Ba}(\text{NO}_3)_2] = \frac{0.15}{2} = 0.0750 \text{ M} \Rightarrow [\text{NO}_3^-] = 0.150$$

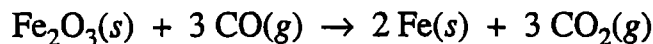
$$\Rightarrow \text{Total } [\text{NO}_3^-] = 0.600 \text{ M}$$

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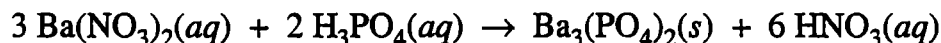
(a) Iron(III) oxide can be reduced with carbon monoxide according to the following equation.



A 16.2 L sample of $\text{CO}(g)$ at 1.50 atm and $200.^\circ\text{C}$ is combined with 15.39 g of $\text{Fe}_2\text{O}_3(s)$.

- How many moles of $\text{CO}(g)$ are available for the reaction?
- What is the limiting reactant for the reaction? Justify your answer with calculations.
- How many moles of $\text{Fe}(s)$ are formed in the reaction?

(b) In a reaction vessel, 0.600 mol of $\text{Ba}(\text{NO}_3)_2(s)$ and 0.300 mol of $\text{H}_3\text{PO}_4(aq)$ are combined with deionized water to a final volume of 2.00 L. The reaction represented below occurs.



- Calculate the mass of $\text{Ba}_3(\text{PO}_4)_2(s)$ formed.
- Calculate the pH of the resulting solution.
- What is the concentration, in mol L^{-1} , of the nitrate ion, $\text{NO}_3^-(aq)$, after the reaction reaches completion?

$$(ai) PV = nRT \rightarrow (1.5)(16.2) = n(0.0821)(473) \rightarrow n = 0.63 \text{ moles of CO}$$

$$200^\circ\text{C} \rightarrow 200 + 273 = 473 \text{ K}$$

$$(aii) \text{Molecular mass of } \text{Fe}_2\text{O}_3 = 159.7 \text{ g/mol}, 15.39 \text{ g } \text{Fe}_2\text{O}_3 \text{ is } 15.39 / 159.7 = 0.096 \text{ moles}$$

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

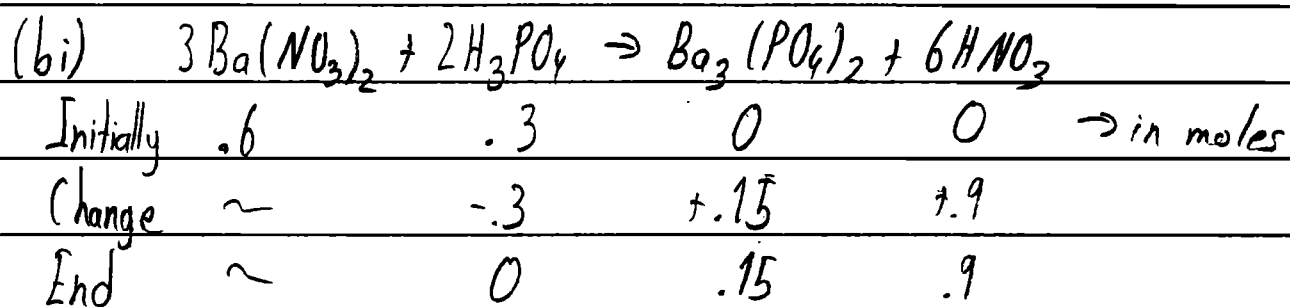


Initially .096 .63 0 0 \rightarrow in moles

Change -.096 ~ +.192 ~

End 0 ~ .192 ~

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$$\text{Molecular mass of } \text{Ba}_3(\text{PO}_4)_2 = 601.94 \text{ g/mol}$$

$$\text{Mass of } \text{Ba}_3(\text{PO}_4)_2 \text{ formed} = 0.15 \cdot 601.94 = 90.29 \text{ g} \quad \left(\text{moles} = \frac{\text{grams}}{\text{molecular mass}} \right)$$

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

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

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

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

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

$$[\text{NO}_3^-] = \frac{\text{moles of solute}}{\text{L of solution}} = \frac{.9}{2} = 0.45 \text{ M}$$

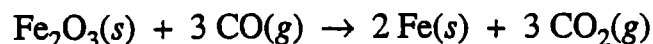
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2C1

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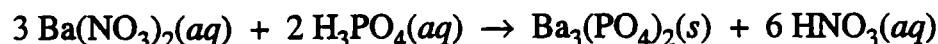
(a) Iron(III) oxide can be reduced with carbon monoxide according to the following equation.



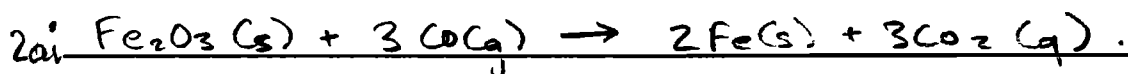
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- Calculate the pH of the resulting solution.
- What is the concentration, in mol L^{-1} , of the nitrate ion, $\text{NO}_3^-(aq)$, after the reaction reaches completion?



moles of $\text{CO}(g) = ?$

Given equation $PV = nRT$ ($P = \text{pressure}$, $V = \text{volume}$, $n = \# \text{ of moles}$, $R = \text{gas constant}$)

$P = 1.5 \text{ atm}$

$T = \text{temperature (absolute)}$

$V = 16.2 \text{ L}$

$T = (200 + 273) \text{ K}$

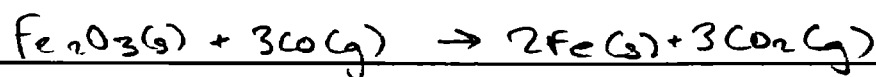
$$\Rightarrow 1.5(16.2) = n(0.0821)(200 + 273)$$

$R = 0.0821$

$$\Rightarrow n = 0.6258 \text{ moles of } \text{CO}(g) \text{ available.}$$

ii. # moles of $\text{Fe}_2\text{O}_3(s)$ available = $n = \frac{m}{M} \left[\frac{\text{mass given}}{\text{molar mass}} \right] = \frac{15.39}{159.7} = 0.0964$ moles.

$M \text{ of } \text{Fe}_2\text{O}_3 = 159.7 \text{ g/mol}$



1 : 3 : 2 : 3

(Reacting ratio (moles))

0.0964 moles

(Given)

GO ON TO THE NEXT PAGE.

→ # moles CO which react with 0.0964 moles $\text{Fe}_2\text{O}_3 =$
 $0.0964 \times 3 = 0.2891$ moles.

this value is less than the given value of CO(g) available
 (0.6258 moles) → $\text{Fe}_2\text{O}_3(\text{s})$ is the limiting reagent while
 CO(g) is in excess.

iii. By the reacting ratios, $\text{Fe}_2\text{O}_3 : \text{CO} : \text{Fe} : \text{CO}_2$ (moles)
 $1 : 3 : 2 : 3$
 $0.0964 : \quad \quad \quad x$ moles of Fe(s) produced
 ⇒ $x = 0.0964 \times 2 = 0.1928$ moles of Fe(s) formed.

2bi. Reacting ratios (moles) ⇒ $\text{Ba}(\text{NO}_3)_2 : \text{H}_3\text{PO}_4 : \text{Ba}_3(\text{PO}_4)_2 : \text{HNO}_3$
 $3 : 2 : 1 : 6$

initial quantities (moles) ⇒ 0.6 0.3

For limiting reagent: - 0.6 x

$$\Rightarrow x = \frac{0.6 \cdot 2}{3} = 0.4$$

⇒ H_3PO_4 is limiting > initial given
 H_3PO_4

$$\Rightarrow \quad \quad \quad 0.3 \quad \quad x$$

$$\Rightarrow x = \# \text{ moles } \text{Ba}_3(\text{PO}_4)_2 = 0.3/2 = 0.15 \text{ moles.}$$

Molar mass of $\text{Ba}_3(\text{PO}_4)_2 = 191 \text{ g/mol}$

$$\Rightarrow \text{mass of } \text{Ba}_3(\text{PO}_4)_2 = 0.15 \text{ moles} \cdot \frac{191}{1 \text{ mol}} = 28.6 \text{ g of } \text{Ba}_3(\text{PO}_4)_2 \text{ formed.}$$

ii. By reacting ratios # moles HNO_3 formed = $(0.3 \cdot 6)/2 = 0.9$ moles
 HNO_3 dissociates completely into H^+ and NO_3^-

$$\text{pH} = -\log [\text{H}^+] \quad [\text{H}^+] = \frac{0.9 \text{ moles}}{2 \text{ L}} = 0.45 \text{ M} \Rightarrow \text{pH} = -\log 0.45$$

iii. HNO_3 dissociates completely. 2 L so $[\text{H}^+] = [\text{NO}_3^-] = [\text{HNO}_3] = \frac{0.9 \text{ moles}}{2 \text{ L}}$
 $= 0.45 \text{ M.}$

GO ON TO THE NEXT PAGE.