Chemistry 20 – Lesson 33
Gas Volume Stoichiometry

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1. $2\ CH_3OH_{(l)} + 3\ O_{2\,(g)} \longrightarrow 2\ CO_{2\,(g)} + 4\ H_2O_{\,(g)}$

$m_{CH_3OH} = 15\,g$

$M_{CH_3OH} = 32.05\,{}^{g}\!/_{mol}$

$v_{O_2} = ?$

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A. calculate moles

$$n_{CH_3OH} = \frac{15\,g}{32.05\,{}^{g}\!/_{mol}}$$

$$n_{CH_3OH} = 0.47\,mol$$

B. mole ratio

$$\frac{n_{O_2}}{3} = \frac{n_{CH_3OH}}{2}$$

$$\frac{n_{O_2}}{3} = \frac{0.47\,mol}{2}$$

$$n_{O_2} = 0.70\,mol$$

C. calculate volume

$$v_{O_2} = 0.70\,mol(24.8\,{}^{L}\!/_{mol})$$

$$\boxed{v_{O_2} = 17\,L}$$

2. $C_3H_{8\,(g)} + 5\ O_{2\,(g)} \longrightarrow 3\ CO_{2\,(g)} + 4\ H_2O_{\,(g)}$

$m_{C_3H_8} = 15\,g$

$M_{C_3H_8} = 44.11\,{}^{g}\!/_{mol}$

$v_{O_2} = 50\,L$

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A. calculate moles

$$n_{O_2} = \frac{50\,L}{24.8\,{}^{L}\!/_{mol}}$$

$$n_{O_2} = 2.0\,mol$$

B. mole ratio

$$\frac{n_{C_3H_8}}{1} = \frac{n_{O_2}}{5}$$

$$\frac{n_{C_3H_8}}{1} = \frac{2.0\,mol}{5}$$

$$n_{C_3H_8} = 0.40\,mol$$

C. calculate mass

$$m_{C_3H_8} = 0.40\,mol(44.11\,{}^{g}\!/_{mol})$$

$$\boxed{m_{C_3H_8} = 18\,g}$$

3. $2\ H_{2\,(g)} + O_{2\,(g)} \longrightarrow H_2O_{\,(g)}$

$v_{H_2} = ?$ $\quad v_{O_2} = 300\,L$

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A. mole/gas volume ratio

$$\frac{v_{H_2}}{2} = \frac{v_{O_2}}{1}$$

$$\frac{v_{H_2}}{2} = \frac{300\,L}{1}$$

$$\boxed{v_{H_2} = 600\,L}$$

4. $2\,NaCl_{(l)} \longrightarrow 2\,Na_{(l)} + Cl_{2\,(g)}$

$m_{Na} = 100\,000\,g$

$M_{Na} = 22.99\,{}^{g}\!/\!_{mol}$

$v_{Cl_2} = ?$

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A. calculate moles

$$n_{Na} = \frac{100\,000\,g}{22.99\,{}^{g}\!/\!_{mol}}$$

$$n_{Na} = 4349.7\,mol$$

B. mole ratio

$$\frac{n_{Cl_2}}{1} = \frac{n_{Na}}{2}$$

$$\frac{n_{Cl_2}}{1} = \frac{4349.7\,mol}{2}$$

$$n_{Cl_2} = 2174.86\,mol$$

C. calculate volume

$$v_{Cl_2} = 2174.86\,mol(24.8\,{}^{L}\!/\!_{mol})$$

$$\boxed{v_{Cl_2} = 53.9\,kL}$$

5. $CH_{4\,(g)} + 2\,O_{2\,(g)} \longrightarrow CO_{2\,(g)} + 2\,H_2O_{\,(g)}$

$v_{CH_4} = 2.00\times10^{6}\,L$ @ $0^{\circ}C, 120\,kPa$

$v_{O_2} = ?@SATP$

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A. calculate moles

$$n_{CH_4} = \frac{pv}{RT}$$

$$n_{CH_4} = \frac{120\,kPa \times 2.00\times10^{6}\,L}{8.31\frac{kPa\cdot L}{mol\cdot K}\times 273\,K}$$

$$n_{CH_4} = 1.06\times10^{5}\,mol$$

B. mole ratio

$$\frac{n_{O_2}}{2} = \frac{n_{CH_4}}{1}$$

$$\frac{n_{O_2}}{2} = \frac{1.06\times10^{5}\,mol}{1}$$

$$n_{O_2} = 2.12\times10^{5}\,mol$$

C. calculate volume

$$v_{O_2} = 2.12\times10^{5}\,mol \times 24.8\,{}^{L}\!/\!_{mol}$$

$$\boxed{v_{O_2} = 5.25\times10^{6}\,L \text{ or } 5.25\,ML}$$

6. $2\,H_2O_{2\,(aq)} \longrightarrow 2\,H_2O_{\,(l)} + O_{2\,(g)}$

$c_{H_2O_2} = 0.88\,{}^{mol}\!/\!_{L}$

$v_{H_2O_2} = ?$

$v_{O_2} = 500\,mL$

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A. calculate moles

$$n_{O_2} = \frac{0.500\,L}{24.8\,{}^{L}\!/\!_{mol}}$$

$$n_{O_2} = 0.02016\,mol$$

B. mole ratio

$$\frac{n_{H_2O_2}}{2} = \frac{n_{O_2}}{1}$$

$$\frac{n_{H_2O_2}}{2} = \frac{0.02016\,mol}{1}$$

$$n_{H_2O_2} = 0.04032\,mol$$

C. calculate volume

$$v_{H_2O_2} = \frac{0.04032\,mol}{0.88\,{}^{mol}\!/\!_{L}}$$

$$\boxed{v_{H_2O_2} = 46\,mL}$$

7. $CH_{4\,(g)}$ + $2\,H_2O_{\,(g)}$ $\longrightarrow$ $CO_{2\,(g)}$ + $4\,H_{2\,(g)}$

$m_{H_2O} = 1.00\times10^6\,g$ $\qquad$ $v_{H_2} = ?$

$M_{H_2O} = 18.02\,{}^{g}\!/_{mol}$ $\qquad$ $@\,25^\circ C, 120\,kPa$

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A. calculate moles

$$n_{H_2O} = \frac{1000\,000\,g}{18.02\,{}^{g}\!/_{mol}}$$

$$n_{H_2O} = 55\,493.9\,mol$$

B. mole ratio

$$\frac{n_{H_2}}{4} = \frac{n_{H_2O}}{2}$$

$$\frac{n_{H_2}}{4} = \frac{55\,493.9\,mol}{2}$$

$$n_{H_2} = 110\,987.8\,mol$$

C. calculate volume

$$v_{H_2} = \frac{nRT}{p}$$

$$v_{H_2} = \frac{110\,987.8\,mol \times 8.31\,\frac{kPa\cdot L}{mol\cdot K} \times 298\,K}{120\,kPa}$$

$$\boxed{v_{H_2} = 2.3\times10^6\,L \text{ or } 2.3\,ML}$$

8. $2\,H_2O_{\,(g)} \longrightarrow$ $2\,H_{2\,(g)}$ + $O_{2\,(g)}$

$m_{H_2O} = 50g$ $\qquad$ $v_{H_2} = ?$ $\qquad$ $v_{O_2} = ?$

$M_{H_2O} = 18.02\,{}^{g}\!/_{mol}$

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A. calculate moles

$$n_{H_2O} = \frac{50\,g}{18.02\,{}^{g}\!/_{mol}}$$

$$n_{H_2O} = 2.77\,mol$$

B. mole ratios

$$\frac{n_{H_2}}{2} = \frac{n_{H_2O}}{2}$$

$$\frac{n_{H_2}}{2} = \frac{2.77\,mol}{2}$$

$$n_{H_2} = 2.77\,mol$$

$$\frac{n_{O_2}}{1} = \frac{n_{H_2O}}{2}$$

$$\frac{n_{O_2}}{1} = \frac{2.77\,mol}{2}$$

$$n_{O_2} = 1.39\,mol$$

C. calculate volumes

$$v_{H_2} = 2.77\,mol \times 22.4\,{}^{L}\!/_{mol}$$

$$\boxed{v_{H_2} = 62.1\,L}$$

$$v_{O_2} = 1.39\,mol \times 22.4\,{}^{L}\!/_{mol}$$

$$\boxed{v_{O_2} = 31.1\,L}$$

9. $2\,C_2H_{2\,(g)}$ + $5\,O_{2\,(g)}$ $\longrightarrow$ $4\,CO_{2\,(g)}$ + $2\,H_2O_{\,(g)}$

$v_{C_2H_2} = 10.0\,L$ $\qquad$ $v_{O_2} =$

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A. mole/gas volume ratio

$$\frac{v_{O_2}}{5} = \frac{v_{C_2H_2}}{2}$$

$$\frac{v_{O_2}}{5} = \frac{10.0\,L}{2}$$

$$\boxed{v_{O_2} = 25.0\,L}$$

10. $Mg_{(s)} + 2\,HCl_{(aq)} \longrightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$

$m_{Mg} = ?$ $\quad v_{H_2} = 0.300\,L$

$M_{H_2O} = 24.31\,{}^{g}\!/_{mol}$ $\quad @\,25^{\circ}C, 105\,kPa$

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A. calculate moles

$$n_{H_2} = \frac{pv}{RT}$$

$$n_{H_2} = \frac{105kPa \times 0.300\,L}{8.31\,\frac{kPa\cdot L}{mol\cdot K} \times 298\,K}$$

$$n_{H_2} = 0.0127\,mol$$

B. mole ratio

$$\frac{n_{Mg}}{1} = \frac{n_{H_2}}{1}$$

$$n_{Mg} = 0.0127\,mol$$

C. calculate mass

$$m_{Mg} = 0.0127mol(24.31\,{}^{g}\!/_{mol})$$

$$\boxed{m_{Mg} = 0.31g}$$

11. $2\,H_{2\,(g)} + O_{2\,(g)} \longrightarrow 2\,H_2O_{\,(g)}$

$v_{H_2} = 11L$ $\quad v_{O_2} = ?$ $\quad v_{H_2O} = ?$

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assume that the gases are all under the same conditions

$$\frac{v_{O_2}}{1} = \frac{v_{H_2}}{2} \qquad \frac{v_{H_2O}}{2} = \frac{v_{H_2}}{2}$$

$$\frac{v_{O_2}}{1} = \frac{11L}{2} \qquad \frac{v_{H_2O}}{2} = \frac{11L}{2}$$

$$\boxed{v_{O_2} = 5.5L} \qquad \boxed{v_{H_2O} = 11L}$$

12. $CH_{4\,(g)} + 2\,O_{2\,(g)} \longrightarrow CO_{2\,(g)} + 2\,H_2O_{\,(g)}$

$m_{CH_4} = 14g$ $\quad v_{CO_2} = ?$

$M_{CH_4} = 16.04\,{}^{g}\!/_{mol}$ $\quad @\,20^{\circ}C, 105\,kPa$

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A. calculate moles

$$n_{CH_4} = \frac{14\,g}{16.04\,{}^{g}\!/_{mol}}$$

$$n_{CH_4} = 0.873\,mol$$

B. mole ratio

$$\frac{n_{CO_2}}{1} = \frac{n_{CH_4}}{1}$$

$$n_{CO_2} = 0.873\,mol$$

C. calculate volume & %error

$$v_{CO_2} = \frac{nRT}{p}$$

$$v_{CO_2} = \frac{0.873\,mol \times 8.31\,\frac{kPa\cdot L}{mol\cdot K} \times 293\,K}{105\,kPa}$$

$$\boxed{v_{CO_2} = 20.2\,L}$$

$$\%error = \frac{exp.\ yield - theo.\ yield}{theo.\ yield} \times 100$$

$$\%error = \frac{19.6 - 20.2}{20.2} \times 100$$

$$\boxed{\%error = -3.2\%}$$

13. $3\,H_{2\,(g)} + N_{2\,(g)} \longrightarrow 2\,NH_{3\,(g)}$

$m_{H_2} = 19.5\,g$ $\quad v_{CO_2} = ?$

$M_{H_2} = 2.02\,{}^{g}\!/\!_{mol}$ $\quad @\,20^{\circ}C, 105\,kPa$

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A. calculate moles

$$n_{H_2} = \frac{19.5\,g}{2.02\,{}^{g}\!/\!_{mol}}$$

$$n_{H_2} = 9.65\,mol$$

B. mole ratio

$$\frac{n_{NH_3}}{2} = \frac{n_{H_2}}{3}$$

$$\frac{n_{NH_3}}{2} = \frac{9.65\,mol}{3}$$

$$n_{NH_3} = 6.44\,mol$$

C. calculate volume & %error

$$v_{NH_3} = 6.44\,mol \times 22.4\,{}^{L}\!/\!_{mol}$$

$$\boxed{v_{NH_3} = 144\,L}$$

$$\%error = \frac{\text{exp. yield} - \text{theo. yield}}{\text{theo. yield}} \times 100$$

$$\%error = \frac{140 - 144}{144} \times 100$$

$$\boxed{\%error = -2.9\%}$$