23. (a) moles of $Cr_2O_7^{2-}$ $= 0.125 \frac{mol}{L} \times 0.0176\ L = 2.20 \times 10^{-3}$ mol

moles of $Fe^{2+} = 2.20 \times 10^{-3}$ mol $Cr_2O_7^{2-} \times \frac{6 \text{ mol } Fe^{2+}}{1 \text{ mol } Cr_2O_7^{2-}} = 0.0132$ mol

$[Fe^{2+}] = \frac{n}{V} = \frac{0.0132 \text{ mol}}{0.0250\ L} =$ **0.528 M**

(b) mass of Fe = mass of $Fe^{2+} = 0.01320 \text{ mol} \times \frac{55.8\ g}{1 \text{ mol}} =$ **0.737 g**

24. (a) $[NH_4NO_3] = \frac{15.5\ g}{0.5000\ L} \times \frac{1 \text{ mol}}{80.0\ g} = 0.3875$ M

moles of $NH_4NO_3 = 0.3875 \frac{mol}{L} \times 0.0100\ L = 3.875 \times 10^{-3}$ mol = moles NaOH

$[NaOH] = \frac{n}{V} = \frac{3.875 \times 10^{-3} \text{ mol}}{0.0250\ L} =$ **0.155 M**

(b) volume of $NH_3 = 3.875 \times 10^{-3}$ mol NaOH $\times \frac{1 \text{ mol } NH_3}{1 \text{ mol NaOH}} \times \frac{22.4\ L\ NH_3}{1 \text{ mol } NH_3} =$ **0.0868 L**

25. (a) moles of $Ba(OH)_2$ (at start) $= 0.0538 \frac{mol}{L} \times 0.0250\ L =$ **1.345 x 10^{-3} mol**

(b) moles of HCl $= 0.104 \frac{mol}{L} \times 0.0230\ L = 2.392 \times 10^{-3}$ mol

moles of $Ba(OH)_2$ (remaining) $= 2.392 \times 10^{-3}$ mol HCl $\times \frac{1 \text{ mol } Ba(OH)_2}{2 \text{ mol HCl}} =$ **1.196 x 10^{-3} mol**

(c) moles of $Ba(OH)_2$ (reacted) = moles $Ba(OH)_2$ (at start) – moles $Ba(OH)_2$ (remaining)
$= 1.345 \times 10^{-3} - 1.196 \times 10^{-3} =$ **1.49 x 10^{-4} mol**

(d) moles of $CO_2 = 1.49 \times 10^{-4}$ mol $Ba(OH)_2 \times \frac{1 \text{ mol } CO_2}{1 \text{ mol } Ba(OH)_2} =$ **1.49 x 10^{-4} mol**

(e) volume of $CO_2 = 1.49 \times 10^{-4} \text{ mol} \times \frac{22.4\ L}{1 \text{ mol}} = 3.34 \times 10^{-3}$ L

% CO_2 in air $= \frac{3.34 \times 10^{-3}\ L}{10.0\ L} \times 100\% =$ **0.0334%**

26. mass of CS_2 (based on C) $= 17.5\ g\ C \times \frac{1 \text{ mol C}}{12.0\ g\ C} \times \frac{1 \text{ mol } CS_2}{5 \text{ mol C}} \times \frac{76.2\ g\ CS_2}{1 \text{ mol } CS_2} = 22.2\ g$

mass of CS_2 (based on SO_2) $= 39.5\ g\ SO_2 \times \frac{1 \text{ mol } SO_2}{64.1\ g\ SO_2} \times \frac{1 \text{ mol } CS_2}{2 \text{ mol } SO_2} \times \frac{76.2\ g\ CS_2}{1 \text{ mol } CS_2} = 23.5\ g$

Since C produces the least amount of CS_2, then the mass of CS_2 produced is **22.2 g.** The SO_2 is present in excess, so the mass of SO_2 used can be calculated arbitrarily based on the mass of C.

mass of SO_2 used $= 17.5\ g\ C \times \frac{1 \text{ mol C}}{12.0\ g\ C} \times \frac{2 \text{ mol } SO_2}{5 \text{ mol C}} \times \frac{64.1\ g\ SO_2}{1 \text{ mol } SO_2} = 37.4\ g$

mass of SO_2 in excess = 39.5 – 37.4 = **2.1 g**

27. mass of NO (based on Cu) = $87.0\text{ g Cu} \times \frac{1\text{ mol Cu}}{63.5\text{ g Cu}} \times \frac{2\text{ mol NO}}{3\text{ mol Cu}} \times \frac{30.0\text{ g NO}}{1\text{ mol NO}} = 27.4\text{ g}$

mass of NO (based on HNO_3) = $225\text{ g }HNO_3 \times \frac{1\text{ mol }HNO_3}{63.0\text{ g }HNO_3} \times \frac{2\text{ mol NO}}{8\text{ mol }HNO_3} \times \frac{30.0\text{ g NO}}{1\text{ mol NO}} = 26.8\text{ g}$

Since HNO_3 produces the least amount of NO, then the mass of NO produced is **26.8 g.**
Now find the mass of Cu in excess, based on the amount of HNO_3 used.

mass of Cu used = $225\text{ g }HNO_3 \times \frac{1\text{ mol }HNO_3}{63.0\text{ g }HNO_3} \times \frac{3\text{ mol Cu}}{8\text{ mol }HNO_3} \times \frac{63.5\text{ g Cu}}{1\text{ mol Cu}} = 85.0\text{ g}$

mass of Cu in excess = 87.0 − 85.0 = **2.0 g**

28. mass of P_4 [based on $Ca_3(PO_4)_2$] = $41.5\text{ g }Ca_3(PO_4)_2 \times \frac{1\text{ mol }Ca_3(PO_4)_2}{310.3\text{ g }Ca_3(PO_4)_2} \times \frac{1\text{ mol }P_4}{2\text{ mol }Ca_3(PO_4)_2}$

$\times \frac{124.0\text{ g }P_4}{1\text{ mol }P_4} = 8.29\text{ g}$

mass of P_4 (based on SiO_2) = $26.5\text{ g }SiO_2 \times \frac{1\text{ mol }SiO_2}{60.1\text{ g }SiO_2} \times \frac{1\text{ mol }P_4}{6\text{ mol }SiO_2} \times \frac{124.0\text{ g }P_4}{1\text{ mol }P_4} = 9.11\text{ g}$

mass of P_4 (based on C) = $7.80\text{ g C} \times \frac{1\text{ mol C}}{12.0\text{ g C}} \times \frac{1\text{ mol }P_4}{10\text{ mol C}} \times \frac{124.0\text{ g }P_4}{1\text{ mol }P_4} = 8.06\text{ g}$

Since C produces the least amount of P_4, then the mass of P_4 produced is **8.06 g.**
Next, calculate the masses of both $Ca_3(PO_4)_2$ and SiO_2 used by the C:

mass of $Ca_3(PO_4)_2$ used = $7.80\text{ g C} \times \frac{1\text{ mol C}}{12.0\text{ g C}} \times \frac{2\text{ mol }Ca_3(PO_4)_2}{10\text{ mol C}} \times \frac{310.3\text{ g }Ca_3(PO_4)_2}{1\text{ mol }Ca_3(PO_4)_2} = 40.3\text{ g}$

mass of $Ca_3(PO_4)_2$ in excess = 41.5 − 40.3 = **1.2 g**

mass of SiO_2 used = $7.80\text{ g C} \times \frac{1\text{ mol C}}{12.0\text{ g C}} \times \frac{6\text{ mol }SiO_2}{10\text{ mol C}} \times \frac{60.1\text{ g }SiO_2}{1\text{ mol }SiO_2} = 23.4\text{ g}$

mass of SiO_2 in excess = 26.5 − 23.4 = **3.1 g**

29. mass of Br_2 (based on $K_2Cr_2O_7$) = $25.0\text{ g }K_2Cr_2O_7 \times \frac{1\text{ mol }K_2Cr_2O_7}{294.2\text{ g }K_2Cr_2O_7} \times \frac{3\text{ mol }Br_2}{1\text{ mol }K_2Cr_2O_7} \times \frac{159.8\text{ g }Br_2}{1\text{ mol }Br_2}$

$= 40.7\text{ g}$

mass of Br_2 (based on KBr) = $55.0\text{ g KBr} \times \frac{1\text{ mol KBr}}{119.0\text{ g KBr}} \times \frac{3\text{ mol }Br_2}{6\text{ mol KBr}} \times \frac{159.8\text{ g }Br_2}{1\text{ mol }Br_2} = 36.9\text{ g}$

mass of Br_2 (based on H_2SO_4) = $60.0\text{ g }H_2SO_4 \times \frac{1\text{ mol }H_2SO_4}{98.1\text{ g }H_2SO_4} \times \frac{3\text{ mol }Br_2}{7\text{ mol }H_2SO_4} \times \frac{159.8\text{ g }Br_2}{1\text{ mol }Br_2}$

$= 41.9\text{ g}$

KBr is the limiting reactant (it produces the least amount of Br_2). $K_2Cr_2O_7$ and H_2SO_4 are in excess.
Calculate the mass of $K_2Cr_2O_7$ and H_2SO_4 present in excess, arbitrarily based on the mass of KBr.

mass of $K_2Cr_2O_7$ used = $55.0\text{ g KBr} \times \frac{1\text{ mol KBr}}{119.0\text{ g KBr}} \times \frac{1\text{ mol }K_2Cr_2O_7}{6\text{ mol KBr}} \times \frac{294.2\text{ g }K_2Cr_2O_7}{1\text{ mol }K_2Cr_2O_7} = 22.7\text{ g}$

mass of $K_2Cr_2O_7$ in excess = 25.0 − 22.7 = **2.3 g**

mass of H_2SO_4 used = $55.0\text{ g KBr} \times \frac{1\text{ mol KBr}}{119.0\text{ g KBr}} \times \frac{7\text{ mol }H_2SO_4}{6\text{ mol KBr}} \times \frac{98.1\text{ g }H_2SO_4}{1\text{ mol }H_2SO_4} = 52.9\text{ g}$

mass of H_2SO_4 in excess = 60.0 − 52.9 = **7.1 g**