1. Permanganate ion reacts with strong acids in an oxidation-reduction reaction to produce Manganese(II) ions and oxygen gas. Write the ***balanced net ionic equation*** for this reaction. Using the table given, calculate the ***molar enthalpy change*** for this reaction. How many ***grams of Calcium Permanganate*** are needed to have 25.00 kJ of heat transferred?

Substance	ΔH_f° (kJ mol^{-1})
$H^+_{(g)}$	1536.3
$H^+_{(aq)}$	0.00
$H_2O_{(g)}$	-241.8
$H_2O_{(l)}$	-285.840
$Ca(MnO_4)_{2(s)}$	-1112
$MnO_4^-{}_{(aq)}$	-518.4
$Mn^{2+}{}_{(aq)}$	-219
$CO_{2(g)}$	-393.5

First we balance the redox reaction:

$$MnO_4^- + H^+ \rightarrow O_2 + Mn^{2+}$$

+7 -2 +1 0 +2

$$4(5\,e^- + 8\,H^+ + MnO_4^- \rightarrow Mn^{2+} + 4\,H_2O)$$
$$5(2\,H_2O + H^+ \rightarrow O_2 + 5\,H^+ + 4\,e^-)$$

$$12\,H^+ + 4\,MnO_4^- \rightarrow 4\,Mn^{2+} + 5\,O_2 + 6\,H_2O$$

Determine ΔH

$$\Delta H = \left[\left(\frac{4 \text{ mol } Mn^{2+}}{\text{mol rxn}}\right)\left(\frac{-219 \text{ kJ}}{\text{mol } Mn^{2+}}\right) + \left(\frac{5 \text{ mol } O_2}{\text{mol rxn}}\right)\left(\frac{0.00 \text{ kJ}}{\text{mol } O_2}\right) + \left(\frac{6 \text{ mol } H_2O}{\text{mol rxn}}\right)\left(\frac{-285.840 \text{ kJ}}{\text{mol } H_2O}\right)\right]$$
$$-\left[\left(\frac{12 \text{ mol } H^+}{\text{mol rxn}}\right)\left(\frac{0.00 \text{ kJ}}{\text{mol } H^+}\right) + \left(\frac{4 \text{ mol } MnO_4^-}{\text{mol rxn}}\right)\left(\frac{-518.4 \text{ kJ}}{\text{mol } MnO_4^-}\right)\right]$$

$$= -517.44 \text{ kJ } (\text{mol rxn})^{-1}$$

Stoichiometry:

$$? \text{ g } Ca(MnO_4)_2 = -25.00 \text{ kJ} \times \frac{1 \text{ mol rxn}}{-517.44 \text{ kJ}} \times \frac{4 \text{ mol } MnO_4^-}{1 \text{ mol rxn}} \times \frac{1 \text{ mol } Ca(MnO_4)_2}{2 \text{ mol } MnO_4^-} \times \frac{277.95 \text{ g } Ca(MnO_4)_2}{1 \text{ mol } Ca(MnO_4)_2}$$

$$= 26.86 \text{ g } Ca(MnO_4)_2$$

2. **_Balance_** the following reactions. Give the **_molecular equation_** when possible.

a. $ClO_4^-{}_{(aq)} + Cr^{2+}{}_{(aq)} \rightarrow Cl^-{}_{(aq)} + Cr(OH)_{3(s)}$

$16\ OH^-{}_{(aq)} + 4\ H_2O_{(l)} + ClO_4^-{}_{(aq)} + 8\ Cr^{2+}{}_{(aq)} \rightarrow Cl^-{}_{(aq)} + 8\ Cr(OH)_{3(s)}$

b. $HNO_{3(aq)} + Au_{(s)} \rightarrow Au^{3+}{}_{(aq)} + NO_{2(g)}$

$6\ HNO_{3(aq)} + Au_{(s)} \rightarrow Au(NO_3)_{3(aq)} + 3\ NO_{2(g)} + 3\ H_2O_{(l)}$

3. Given the following thermochemical equation,

$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} \qquad \Delta H = -65.2\ kJ$

How many **_grams of calcium oxide_** are needed to generate enough energy to increase the temperature of 5.00 g of aluminum ($s = 0.903\ J\ g^{-1}\ °C^{-1}$) from 231.4 K to 299.5 K?

Calculate q

$$q = ms\Delta T = (5.00\ g)(0.903\ J\ g^{-1}\ °C^{-1})(299.5\ K - 231.4\ K)\left(\frac{1\ °C}{1\ K}\right) = 307\ J$$

Stoichiometry

$$?\ g\ CaO = -307\ J \times \frac{1\ mol\ rxn}{-65.2\times10^3\ J} \times \frac{1\ mol\ CaO}{1\ mol\ rxn} \times \frac{56.08\ g\ CaO}{1\ mol\ CaO} = 0.264\ g\ CaO$$

4. Helium gas is found to effuse 6.55 times faster than an unknown gas. Calculate the ***molar mass*** of the unknown gas. What is the ***rms speed*** of the unknown gas at standard temperature?

$$\frac{R_{He}}{R_{unk}} = \sqrt{\frac{M_{unk}}{M_{He}}}$$

$$R_{He} = 6.55R_{unk}$$

$$\frac{6.55R_{unk}}{R_{unk}} = 6.55 = \sqrt{\frac{M_{unk}}{M_{He}}}$$

$$M_{unk} = (6.55)^2 M_{He} = (6.55)^2 \left(4.0026 \text{ g mol}^{-1}\right) = 172 \text{ g mol}^{-1}$$

$$u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\left(8.314 \text{ J mol}^{-1} \text{ K}^{-1}\right)(273.15 \text{ K})}{\left(172\times10^{-3} \text{ kg mol}^{-1}\right)}} = 199.0224 \text{ m s}^{-1}$$

$$= 199 \text{ m s}^{-1}$$

5. Hydrogen, H_2, is prepared by *steam reforming*, in which hydrocarbons are reacted with steam. For CH_4,

$$CH_{4(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3\ H_{2(g)}$$

Calculate the ***enthalpy change $\Delta H°$*** for this reaction, using standard enthalpies of formation.

$$\Delta H = \left[\left(\frac{1 \text{ mol CO}}{1 \text{ mol rxn}}\right)\left(\frac{-110.5 \text{ kJ}}{1 \text{ mol CO}}\right) + \left(\frac{3 \text{ mol H}_2}{1 \text{ mol rxn}}\right)\left(\frac{0.00 \text{ kJ}}{1 \text{ mol H}_2}\right)\right]$$
$$- \left[\left(\frac{1 \text{ mol CH}_4}{1 \text{ mol rxn}}\right)\left(\frac{-74.87 \text{ kJ}}{1 \text{ mol CH}_4}\right) + \left(\frac{1 \text{ mol H}_2\text{O}}{1 \text{ mol rxn}}\right)\left(\frac{-241.8 \text{ kJ}}{1 \text{ mol H}_2\text{O}}\right)\right]$$

$$= +206.2 \text{ kJ } (\text{mol rxn})^{-1}$$

6. Calculate ***ΔH for the reaction***

$2\,C_{(s)} + H_{2(g)} \rightarrow C_2H_{2(g)}$

given the following thermochemical equations

$-1(C_2H_{2(g)} + 5/2\,O_{2(g)} \rightarrow 2\,CO_{2(g)} + H_2O_{(l)} \quad \Delta H = -1299.6\text{ kJ})$

$2(C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} \quad \Delta H = -395.5\text{ kJ})$

$H_{2(g)} + \frac{1}{2}\,O_{2(g)} \rightarrow H_2O_{(l)} \quad \Delta H = -285.8\text{ kJ}$

$$\Delta H = -(-1299.6\text{ kJ}) + (2)(-395.5\text{ kJ}) + (1)(-285.8\text{ kJ}) = 222.8\text{ kJ}$$

7. An 18.6-mL volume of hydrochloric acid reacts completely with a solid sample of $MgCO_3$. The reaction is

$$2\,HCl_{(aq)} + MgCO_{3(s)} \rightarrow CO_{2(g)} + H_2O_{(l)} + MgCl_{2(aq)}$$

The volume of CO_2 formed is 159 mL at 23°C and 731 mmHg. What is the ***molarity of the HCl*** solution?

$$?\frac{\text{mol HCl}}{\text{L}} = \frac{\left(\frac{(159\times10^{-3}\text{ L})(731\text{ mmHg})}{(62.364\text{ L mmHg mol}^{-1}\text{ K}^{-1})(296\text{ K})}\right)}{18.6\text{ mL}} \times \frac{1\text{ mL}}{10^{-3}\text{ L}} \times \frac{2\text{ mol HCl}}{1\text{ mol }CO_2} = 0.677\text{ M HCl}$$