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**WS 8.1 Stoichiometry: Mole to Mole Conversions**

1. The reaction that takes place in an alkaline flashlight battery as the battery is discharged is:

Zn + MnO2 + H2O  Zn(OH)2 + MnO(OH)

*Remember to balance the equation*.

a. How many moles of Zn react when 0.200 moles of MnO(OH) is formed? *(0.100)*

b. How many moles of H2O react with 0.150 mol of Zn? *(0.300)*

c. how many moles of Zn(OH)2 are formed when 0.100 moles MnO2 reacts? *(0.050)*

d. How many mole of H2O react when 0.600 moles of MnO2 reacts? *(0.600)*

2. Hydrazine, N2H4, and hydrogen, H2O2, have been used as rocket propellants. They react according to the equation:

H2O2 + N2H4   N2 + H2O

a. How many moles of N2 are formed from 0.0250 moles of N2H4? *(0.0250)*

b. How many moles of H2O2 are required if 1.35 moles of H2O is to be produced? *(0.675)*

c. How many moles of H2O are formed if 1.87 moles of N2 is produced? *(7.48)*

3. During the naval battles of the South Pacific in World War II, the U.S. Navy produced smoke screens by spraying titanium tetrachloride into the moist air where it reacted according to the equation:

TiCl4 + H2O   TiO2 + HCl

a. How many moles of H2O are needed to react with 6.50 moles of TiCl4? *(13.0)*

b. How many moles of HCl are formed when 8.44 moles of TiCl4 reacts? *(33.8)*

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4. How many moles of sodium will react with water to produce 4.0 moles of hydrogen in the following reaction? *(8.0)*

Na + H2O  \_ NaOH + H2

5. How many moles of lithium chloride will be formed by the reaction of chlorine with 0.046 moles of lithium bromide in the following reaction? *(0.046)*

LiBr + Cl2  LiCl + Br2

6. Aluminum will react with sulfuric acid in the following reaction:

Al + H2SO4   Al2(SO4)3 +\_ H2

How many moles of H2SO4 will react with 18 moles of Aluminum? *(27)*

7. In the above reaction, how many moles of each product will be produced? *(9.0; 27)*

8. Propane burns in excess oxygen according to the following reaction.

C3H8 + O2   CO2 + H2O

How many moles of carbon dioxide are formed from 3.85 moles of propane? *(11.6)*

9. Using the equation from #8, if 0.647 moles of oxygen is used in the burning of propane, how many moles each of CO2 and H2O are produced? How many moles of C3H8 are consumed? *(0.388; 0.518; 0.130)*

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**WS 8.2 Stoichiometry involving grams**

1. Consider the reaction :

4 Na(s) + O2 (g)  2 Na2O (s)

a. How many moles of sodium are required to produce 120 grams of sodium oxide? *(3.9)*

b. How many moles of oxygen gas are required react with 145.5 grams of sodium? *(1.582)*

c. How many moles of sodium oxide are produced if 75.3 grams of oxygen gas are used? *(4.71)*

2. In the reaction:

AlCl3 (aq) + 4 NaOH (aq)  NaAlO2 (aq) + 3 NaCl (aq) + 2 H2O (l)

a. How many moles of sodium hydroxide will react with 125 grams of aluminum chloride?

*(3.75)*

b. How many moles of water are produced when 56 grams of sodium hydroxide react with excess aluminum chloride? *(0.70)*

c. How many moles of sodium hydroxide are needed to produce 500 grams of sodium chloride? *(11.4)*

3. Glucose is used as a source of energy by the human body. The overall reaction in the body is

C6H12O6 + O2   CO2 + H2O

a. Calculate the number of moles of oxygen needed to oxidize 12.5 grams of glucose?*(0.417)*

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4. Ammonia is synthesized from hydrogen and nitrogen according to the following equation.

N2 + H2   NH3

a. If an excess of nitrogen is reacted with 3.41 grams of hydrogen, how many moles of ammonia can be produced? *(1.14)*

5. If 120.0 grams of sodium carbonate reacts with calcium hydroxide, how many grams of sodium hydroxide are formed? *(90.6)*

Na2CO3 + Ca(OH)2  2 NaOH + CaCO3

6. When 80.0 grams of calcium chloride react with silver nitrate, how many grams of silver chloride are produced? *(207)*

CaCl2 + 2 AgNO3  Ca(NO3)2 + 2 AgCl

7. If 90.0 grams of barium chloride reacts with sulfuric acid, how many grams of barium sulfate are produced? *(101)*

BaCl2 + H2SO4  BaSO4 + 2 HCl

8. If 500 grams of potassium iodide reacts with lead acetate, what mass of lead iodide is formed? *(700)*

Pb(C2H3O2)2 + 2 KI  PbI2 + 2 KC2H3O2

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**WS 8.3 More Stoichiometry Problems Involving Grams**

1. In a single displacement reaction, 9.23 grams of aluminum react with excess hydrochloric acid. How many moles of hydrogen will be produced? *(0.513)*

2. Calculate the mass of silver bromide produced from 22.5 grams of silver nitrate in the following reaction: *(24.9)*

AgNO3 + MgBr2   AgBr + Mg(NO3)2

3. What mass of acetylene, C2H2, will be produced from the reaction of 90.0 grams of calcium carbide, CaC2, with water in the following reaction? *(36.5)*

CaC2 + H2O  C2H2 + Ca(OH)2

4. Chlorine gas can be produced in the laboratory by adding concentrated hydrochloric acid to manganese (IV) oxide in the following reaction. Calculate the mass of MnO2 needed to produce 23 grams of Cl2 *(28)*

MnO2 +\_ HCl  MnCl2 + H2O + Cl2

5. How many grams of oxygen are produced by heating 400 grams of potassium chlorate? *(156.6)*

2 KClO3  2 KCl + 3 O2

6. How many grams of sodium hydroxide will react with 150 grams of phosphoric acid? *(183.7)*

H3PO4 + 3 NaOH  3 HOH + Na3PO4

7. How many grams of calcium carbonate are required in the preparation of 50.0 grams of calcium oxide?

*(89.2)*

CaCO3  CaO + CO2

8. If 600 grams of calcium hydroxide are neutralized with nitric acid, how many grams of nitric acid are needed? *(1022)*

Ca(OH)2 + 2HNO3  Ca(NO3)2 + 2H2O

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9. How many grams of potassium chlorate are needed in the preparation of 70.0 grams of oxygen? *(179)*

2KClO3  2KCl + 3O2

10. When 50.0 grams of magnesium react with silver nitrate in solution, how many grams of silver are prepared? *(444*)

Mg + 2AgNO3  Mg(NO3)2 + 2Ag

11. If 75.0 grams of copper react with mercuric nitrate (in solution), how many grams of mercury can be displaced? *(237)*

Cu + Hg(NO3)2   Cu(NO3)2 + Hg

12. When 60.0 grams of aluminum react with hydrochloric acid, how many grams of aluminum chloride are prepared? *(297)*

Al + HCl  \_ AlCl3 + H2

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**WS 8.4 More Stoichiometry Problems (some without equations)**

1. If 150 grams of mercuric oxide are decomposed, what mass of oxygen is formed? (11.1)

HgO   Hg + O2

2. Calculate the mass of in grams of carbon needed to produce 80 grams of carbon dioxide by burning. (21.8)

C + O2   CO2

3. Calculate the mass of sulfur which will react with 40 grams of copper. (10.1)

Cu + S   Cu2S

4. Calculate the mass of oxygen released by the action of water on 10.0 grams of sodium peroxide. (2.05)

Na2O2 + HOH   NaOH + \_O2

5. Calculate the mass of silver formed by heating 10 grams of silver oxide. (9.3)

Ag2O   Ag + O2

6. If 50.0 grams of oxygen react with magnesium, what mass of MgO is formed? (125.9)

7. When 70 grams of zinc react with dilute sulfuric acid, what mass of hydrogen is formed? (2.14)

8. How much aluminum must be oxidized to form 85 grams of aluminum oxide? (45)

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9. How many grams of magnesium chloride are formed when 30.0 grams of magnesium react with hydrochloric acid? (117.7)

10. When 90 grams of sodium hydroxide are neutralized with sulfuric acid, what mass of sodium sulfate is formed? (159.9)

11. Sixty-five grams of calcium hydroxide are formed when calcium oxide reacts with water. How much

CaO is required to prepare this quantity? (49.2)

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**Ws 8.5 Limiting Reactants**

1. Calcium hydroxide, used to neutralize acid spills, reacts with hydrochloric acid according to the following equation:

Ca(OH)2 + HCl   CaCl2 + H2O

If you have spilled 6.3 moles of HCl and put 2.8 moles of calcium hydroxide on it, which substance is the

limiting reactant?

2. Aluminum oxidizes according to the following equation:

Al + O2   Al2O3

Powdered aluminum (0.048 moles) is placed into a container containing 0.030 moles of oxygen. What is

the limiting reactant?

3. Chlorine can replace bromine in bromide compounds forming a chloride compound and elemental bromine. Write a equation showing the displacement of potassium bromide with chlorine gas. Then solve the following: when 0.855 grams of chlorine gas and 3.205 grams of potassium bromide are mixed in solution, which is the limiting reactant? How many grams of bromine are formed? (1.92)

4. A process by which zirconium metal can be produced from the mineral zirconium (IV) orthosilicate, ZrSiO4, starts by reacting it with chlorine gas to form zirconium (IV) chloride.

ZrSiO4 +\_ Cl2   ZrCl4 + SiO2 + O2

What mass of ZrCl4 can be produced if 862 grams of ZrSiO4 and 950.0 grams of Cl2 are available? (You must first determine the limiting reactant). (1096.7)

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5. Heating zinc sulfide in the presence of oxygen yields the following:

ZnS + O2   ZnO +\_ SO2

If 1.72 grams of ZnS is heated in the presence of 3.04 grams of O2, which reactant will be used up?

6. Use the following equation for the oxidation of aluminum in the following problems.

Al + O2   Al2O3

a. How much aluminum oxide will be produced if 32 grams of aluminum and 26 grams of oxygen are available? (55g)

b. How many moles of aluminum oxide are formed from the reaction of 0.00638 moles of O2

and 0.00915 moles of aluminum? (0.00425 mol)

c. If 3.17 grams of aluminum and 2.55 grams of oxygen gas are available, which reactant is limiting?

7. In the production of copper from ore containing copper (II) sulfide, the ore is first roasted to change it to the oxide according to the following equation:

CuS + O2   CuO + SO2

a. If 100 grams of copper sulfide and 56 grams of oxygen gas are available, which reactant is limiting?

b. What mass of copper oxide can be formed from the reaction of 18.7 grams of copper sulfide and 12.0 grams of oxygen gas? (15.6)

8. A reaction such as the one shown here is often used to demonstrate a single replacement reaction:

CuSO4 + Fe   Cu + Fe2(SO4)3

If you place 0.092 moles of iron filings in a solution containing 0.0158 moles of copper sulfate, what is the limiting reactant? How many moles of iron sulfate will form? (0.0053)

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**WS 8.6 Stoichiometry Review**

1. Consider the reaction: Mg + HCl   MgCl2 + H2

a. How many moles of hydrogen gas can be produced if 5.5 moles of hydrochloric acid is provided

(assuming an excess of magnesium)? (2.8)

b. If 20.0 grams of magnesium reacts with hydrochloric acid, how many grams of magnesium chloride are produced? (78.4)

c. If 2.5 moles of hydrochloric acid is provided, how many grams of hydrogen gas can be produced? (2.5)

d. How much magnesium must be present to produce 100 grams of magnesium chloride? (25.5)

2. Consider the reaction: \_ NaI + Cl2  NaCl + I2

a. How many grams of chlorine gas must be reacted with sodium iodide if 10.0 grams of sodium

chloride are needed? (6.07)

b. What is the limiting reactant if 150 grams of sodium iodide is combined with 2 moles of chlorine gas?

c. Using the information from #2b, calculate what mass of sodium chloride can be produced. (58.5)

3. Write a balanced equation for the combustion of methane (CH4)

a. If 3.7 moles of CH4 are combined with 8 moles of oxygen gas, how many moles of carbon dioxide are produced? (3.7)

b. How many moles of water are produced if 2.5 moles of carbon dioxide are produced? (5.0)

c. Calculate the mass of water produced if 125.0 grams of oxygen are consumed. (70.31)

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4. Consider the equation: Li + CuCl2   LiCl + Cu

a. Calculate the moles of lithium chloride produced when 3.5 moles of copper chloride is used. (7.0)

b. If 150.0 grams of lithium is reacted with 2.0 moles of copper chloride, what mass of lithium chloride can be produced? (169.6)

c. What mass of copper is produced from 18 grams of lithium and 375 grams of copper chloride? (83)

d. How many moles of copper chloride are needed if 25.0 grams of lithium are used? (1.81)

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**WS 8.7 Energy and Stoichiometry – Thermochemical Equations**

1. Calculate H for a process in which a 5.8 gram sample of methane is burned at constant pressure. (H = –890 kJ/mole methane) (-322.6 kJ)

2. The equation for the fermentation of glucose to alcohol and carbon dioxide is: C6H12O6  2 C2H5OH + 2 CO2

The enthalpy change for the reaction is –67 kJ. Is the reaction endothermic or exothermic? Is

energy, in the form of heat, absorbed or released as the reaction occurs?

3. For the reaction

S (s) + O2 (g)  SO2 (g) H = -296 kJ/mole



a. How much heat is released when 275 grams of sulfur is burned in excess oxygen? (-2535.8 kJ)

b. How much heat is released when 25 mol of sulfur is burned in excess oxygen? (-7400 kJ)

c. How much heat is released when 150.0 grams of sulfur dioxide is produced? (-692.7 kJ)

4. Calculate the enthalpy change when 1.00 grams of methane is burned in excess oxygen according to the reaction: (-55.7 kJ)

CH4 (g) + 2 O2 (g)  CO2 (g) + 2 H2O (l) H = -891 kJ/mole methane

5. Calculate the energy change when 15 grams of carbon dioxide is produced from the reaction: C(s) + O2 (g)  CO2 (g) H = -393.51 kJ/mole (-134.2 kJ)

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6. Calculate the enthalpy change for the reaction: P4(s) + 6 Cl2(g)4PCl3(g) H = -2710 kJ if 114.9 grams of chlorine is consumed. (-730.9 kJ)

7. Determine the energy released when 9.73 moles of sulfur dioxide is produced in the reaction:   
 2 ZnS(s) + 3 O2(g)  2 ZnO(s) + 2 SO 2(g) H = -927.54 kJ/mole ZnS

a. Is this reaction endothermic or exothermic?

8. Calculate the mass of water produced in the reaction below if 1925.6 kJ of energy is released. (55.4)

2 H2(g) + O2(g)2 H2O(l) H = -1251.2 kJ/mole O2

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**WS 8.8 Hess’ Law**

1. Calculate the change in enthalpy for each of the following reactions: A. 2 NO2(g) → N2O4(g)

N2(g) + 2 O2(g) → 2 NO2(g) H = 67.8 kJ N2(g) + 2 O2(g) → N2O4(g) H = 9.67 kJ

B. C(s) + 2 H2(g) → CH4(g)

C(s) + O2(g) → CO2(g) H = -393.5 kJ

2 H2(g) + O2(g) → 2 H2O(l) H = -571.66 kJ CO2(g) + 2 H2O(l) → CH4(g) + 2 O2(g) H = 890.37 kJ

C. Sn (s) + 2 Cl2 (g) → SnCl4 (l)

Sn (s) + Cl2(g) → SnCl2(s) H = -325 kJ

SnCl2 (s) + Cl2 (g) → SnCl4 (l) H = -186 kJ

D. Mn (s) + 02 (g) → MnO2 (s)

MnO2 (s) + Mn (s) → 2 MnO (s) H = -240 kJ

2 MnO2 (s) → 2 MnO (s) + 02 (g) H = +264 kJ

E. SnO2 (s) + 2H2 (g) → Sn (s) + 2 H20 (l)

Sn (s) + 02 (g) → SnO2 (s) H = -580.7 kJ

H2 (g) + 1/2 02 (g) → H20 (l) H = -285.8 kJ

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**WS 8.9 More Hess’ Law**

A. 2 Mg (s) + SiCl4 (l) → Si (s) + 2 MgCl2 (s)

SiCl4 (l) → Si (s) + 2 Cl2 (g) H = +687 kJ

Mg (s) + Cl2 (g) → MgCl2 (s) H = -641 kJ

B. N2 (g) + 2 H2 (g) → N2H4 (l)

H2 (g) + 1/2 02 (g) → H20 (g) H = -242 kJ

N2 (g) + 2 H20 (g) → N2H4 (l) + 02 (g) H = +534 kJ

C. CH4 (g) + 2 02 (g) → C02 (g) + 2 H20 (l)

C (s) + 2 H2 (g) → CH4 (g) H =-74.8 kJ  
 C (s) + O2 (g) → CO2 (g) H = -393.5 kJ  
 H2 (g) + 1/2 O2 (g) → H2O (l) H = -235.8 kJ

D. 2 C2H6(g) + 7 02(g) → 4 C02(g) + 6 H20(g)

2 C(s) + 3 H2(g) → C2H6(g) H = -84.7 kJ  
C(s) + 02(g) → C02(g) H = -393.5 kJ H2(g) + 1/2 02(g) → H20(g) H = -241.8 kJ

E. 2 N2O3(g) → 2 N2(g) + 3 O2(g)

N2O3(g) → NO(g) + NO2(g) H = 39.7 kJ

½ N2(g) + ½ O2(g) → NO(g) H = 90.4 kJ

½ N2(g) + O2(g) → NO2(g) H = 33.8 kJ

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**WS 8.10 Even More Hess’ Law**

A. C6H4(OH)2 (aq) + H2O2 (aq)  C6H4O2 (aq) + 2 H2O (l)

C6H4(OH)2 (aq)  C6H4O2 (aq) + H2 (g) H = 177.4 kJ H2 (g) + O2 (g)  H2O2 (aq) H = -191.2 kJ H2 + ½ O2 (g)  H2O (g) H = -241.8 kJ

H2O (g)  H2O (l) H = -43.8 kJ

2. Using the equation: O3 + O  2O2, calculate the enthalpy change which occurs when 180 grams of oxygen (O2) is produced.

O3 (g) + Cl (s)  O2 (g) +ClO (g) H = -126 kJ O2 (g) + Cl (s)  O (g) + ClO (g) H = 268 kJ

3. Calculate the energy released (or absorbed) when 23.5 grams of sodium bromide is reacted in the reaction: ½ Cl2 (g) + NaBr (s)  NaCl (s) + ½ Br2 (l)

CaO (s) + Cl2 (g)  CaOCl2 (s) H = -110.9 kJ H2O + CaOCl2 (s) + 2NaBr (s)  2NaCl(s) + Ca(OH)2 (s) + Br2 (l) H = = -60.2 kJ Ca(OH)2 (s)   CaO (s) + H2O (l) H = 65.1 kJ

4. Determine if the equation :Cu (s) + ½ O2 (g)  CuO (s) is exothermic or endothermic.

2 Cu (s) + S (s)  Cu2S (s) H = -79.5 kJ S (s) + O2 (g)  SO2 (g) H = -297 kJ Cu2S (s) + 2O2 (g)  2CuO (s) + SO2 (g) H = -527.5 kJ

5. In the equation: 4 NH3 (g) + 3 O2 (g)  2N2 (g) + 6 H2O (g), how much energy is released (or absorbed) if 1.5 moles of oxygen is consumed?

4 NH3 (g) + 7 O2 (g)  4 NO2 (g) + 6 H2O (g) H = = 2740 kJ

6NO2 (g) + 8NH3 (g)  7N2 (g) + 12 H2O (g) H = -2740 kJ

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6. Considering the equation: 3 Mg (s) + N2(g)  Mg3N2(s). What is the enthalpy change if 125.75 grams of Mg3N2 is produced.?

3Mg (s) + 2NH3 (g)  Mg3N2 (s) + 3H2(g) H = -371 kJ

½ N2 (g) + 3/2 H2 (g)  NH3 (g) H = -46 kJ

7. Use this equation to answer the following: Mg (s) + N2 (g) + 3 O2 (g)  Mg(NO3)2 (s). How many moles of magnesium were used if 207 kJ of energy was released?

8 Mg (s) + Mg(NO3)2  Mg3N2 (s) + 6 MgO (s) H = -3884 kJ Mg3N2 (s)  3 Mg (s) + N2 (g) H = 463 kJ

2MgO (s)  2 Mg (s) + O2 (g) H = 1203 kJ

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**WS 8.11 Hess’ Law Review Worksheet**

1. H2S(g) + 3/2O2(g)H2SO3(l) H =

H2O(l) +SO2(g) H2SO3(l) H = -15.5 kJ S(s) + O2(g) SO2(g) H = -74.3 kJ S(s) + H2O(l) H2S(g) + 1/2O2(g) H = 38.7 kJ

2. C(s) + O2(g) CO2(g) H =

H2(g) + ½ O2(g) H2O(l) H = -571.6 kJ C2H6(g) 2C(s) + 3H2(g) H = 169.4 kJ

C2H6(g) + 7/2 O2(g) 2CO2(g) + 3H2O(l) H = -3121 kJ

3. H2O(g)H2O(l) H =

H2SO4(l) H2S(g) + 2O2(g) H = 392.5 kJ H2SO4(l) SO3(g) + H2O(g) H = 102.5 kJ SO3(g) + H2O(l) H2S(g) + 2O2(g) H = 345 kJ

4. 2CO2(g) + 2H2O(l) CH3COOH(l) + 2O2(g) H =

C(graphite) + O2(g) CO2(g) H = -861.9 kJ

2H2(g) + O2(g) 2H2O(l) H = -1251.2 kJ

2C(graphite) + 2H2(g) + O2(g) CH3COOH(l) H = -1069.6 kJ

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5. Fe(s) + CO2(g) FeO(s) + CO(g) H =

Fe2O3(s) + 3CO(g) 2Fe(s) + 3CO2(g) H = -69 kJ

3Fe2O3(s) + CO(g) 2Fe3O4(s) + CO2(g) H = -117 kJ Fe3O4 + CO(g) 3FeO(s) + CO2(g) H = -54 kJ

6. Zn(s) + 1/8S8(s) + 2O2(g)  ZnSO4(s) H =

Zn(s) + 1/8S8(s)  ZnS(s) H = -183.92 kJ

2ZnS(s) + 3O2(g)  2ZnO(s) + 2SO 2(g) H = -927.54 kJ

2SO2(g) + O2(g) 2SO 3(g) H = -196.04 kJ ZnO(s) + SO3(g) ZnSO 4 (s) H = -230.32 kJ

7. For the reaction: CH2O(g) + H2(g) CH4O(l) (H = ?) ; calculate the enthalpy change when 190 grams of CH2O is   
 reacted.

CH2O(g) + N2(g) + 3H2(g) N2H4(l) + CH4O(l) H = 74 kJ N2H4(l) + H2(g 2NH3(g) H = -36 kJ N2(g) + 3H2(g 2NH3(g) H = -92 kJ

8. Calculate the hydrogen produced in the reaction: CH4(g) C(s) + 2H2(g) (H =?) when the enthalpy change for this reaction is 237.5kJ.

C(s) + O2(g)CO2(g) H = -787 kJ H2O(l)  H2(g) + 1/2O2(g) H = 571.6 kJ CH4(g) + 2O2(g)CO2(g) + 2H2O(l) H = -1781 kJ

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