NAME KEY DATE HOUR

Hess's Law Worksheet

Directions: Use the thermochemical equations shown below each reaction to determine its enthalpy.

1. $4PCl_5(g) \rightarrow P_4(s) + 10Cl_2(g)$

reverse ~~$P_4(s) + 6Cl_2(g) \rightarrow 4PCl_3(g)$~~ ~~$\Delta H = -27HKJ$~~

$4PCl_3 \rightarrow P_4 + 6Cl_2$ $\Delta H = +271$ kJ

x4 $4PCl_5(g) \rightarrow 4PCl_3(g) + 4Cl_2(g)$ $\Delta H = 27.7KJ \times 4$

$\Delta H = 381.8$ kJ

2. $1/2N_2(g) + 2H_2O(l) \rightarrow NO_2(g) + 2H_2(g)$

reverse ~~$2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$~~ ~~$\Delta H = 115KJ$~~

÷2 $3H_2 + N_2 \rightarrow 2NH_3$ $\Delta H = -115$ kJ / 2

reverse ~~$NO_2(g) + 7/2H_2(g) \rightarrow 2H_2O(l) + NH_3(g)$~~ ~~$\Delta H = -270KJ$~~

$2H_2O + NH_3 \rightarrow NO_2 + \frac{7}{2}H_2$ $\Delta H = +270$ kJ

$\Delta H = 212.5$ kJ

3. $H_2S(g) + 2O_2(g) \rightarrow H_2SO_4(l)$

reverse ~~$H_2SO_4(l) \rightarrow SO_3(g) + H_2O(g)$~~ ~~$\Delta H = 123KJ$~~

$SO_3 + H_2O(g) \rightarrow H_2SO_4(l)$ $\Delta H = -123$ kJ

$H_2S(g) + 2O_2(g) \rightarrow SO_3(g) + H_2O(l)$ $\Delta H = -414KJ$

reverse ~~$H_2O(g) \rightarrow H_2O(l)$~~ ~~$\Delta H = -66KJ$~~

$H_2O(l) \leftrightarrow H_2O(g)$ $\Delta H = +66$ kJ

$\Delta H = -471$ kJ

4. $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$

reverse ~~$2NO_2(g) + 7H_2(g) \rightarrow 2NH_3(g) + 4H_2O(l)$~~ ~~$\Delta H = 199.5KJ$~~

$2NH_3 + 4H_2O \rightarrow 2NO_2 + 7H_2$ $\Delta H = -199.5$ kJ

reverse ~~$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$~~ ~~$\Delta H = 115.5KJ$~~

~~$2NO_2 \rightarrow N_2 + 2O_2$~~ $\Delta H = +115.5$ kJ

x4 ~~$H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$~~ $\Delta H = 61.2KJ \times 4$

$\Delta H = +160.8$ kJ

5. $2H_2O(l) + NH_3(g) \rightarrow NO_2(g) + 7/2H_2(g)$

reverse ~~$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$~~ ~~$\Delta H = -28.7KJ$~~

÷2 $\frac{2}{2}(NH_3) \rightarrow \frac{1}{2}N_2 + \frac{3}{2}H_2$ $\Delta H = +28.7$ kJ ÷ 2

reverse ~~$NO_2(g) + 2H_2(g) \rightarrow 1/2N_2(g) + 2H_2O(l)$~~ ~~$\Delta H = -53.1KJ$~~

$2H_2O + \frac{1}{2}N_2 \rightarrow NO_2 + 2H_2$ $\Delta H = +53.1$ kJ

$\Delta H = 67.45$ kJ

6. $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$

reverse ~~$N_2O_4(g) \rightarrow N_2(g) + 2O_2(g)$~~ ~~$\Delta H = -19.2KJ$~~

$2O_2 + N_2 \rightarrow N_2O_4$ $\Delta H = +19.2 kJ$

~~$N_2O_4(g)$~~ $\rightarrow 2NO_2(g)$ $\Delta H = 116.4KJ$

$\Delta H = 135.6 kJ$

7. $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$

x2 ~~$+2H_2O(l)$~~ $+2NH_3(g) \rightarrow$ ~~$2NO_2(g)$~~ $+ 3/2H_2(g)$ $\Delta H = 168.7KJ \times 2$

x2 ~~$2NO_2(g)$~~ ~~$+3H_2(g)$~~ $\rightarrow N_2(g)$ ~~$+3H_2O(l)$~~ $\Delta H = -132.8KJ \times 2$

$\Delta H = 71.8 kJ$

8. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

~~$CH_3COOH(l) + 2O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$~~ $\Delta H = -871KJ$

reverse ~~$C(graphite) + O_2(g) \rightarrow CO_2(g)$~~ ~~$\Delta H = -394KJ$~~ $\Delta H = +394 kJ \times 2$

x2 ~~$2CO_2 \rightarrow 2C(graphite) + 2O_2$~~

~~$2C(graphite) + 2H_2(g) + O_2(g) \rightarrow CH_3COOH(l)$~~ $\Delta H = -489KJ$

$\Delta H = -572 kJ$

9. $Fe_3O_4 + CO(g) \rightarrow 3FeO(s) + CO_2(g)$

x3 ~~$3Fe_2O_3(s) + CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$~~ $\Delta H = -28.7KJ \times 3$

reverse ~~$3Fe_2O_3(s) + CO(g) \rightarrow 2Fe_3O_4(s) + CO_2(g)$~~ ~~$\Delta H = -48.7KJ$~~

~~$2Fe_3O_4 + CO_2 \rightarrow 3Fe_2O_3 + CO$~~ $\Delta H = +48.7 kJ$

x6 ~~$6Fe(s) + 6CO_2(g) \rightarrow 6FeO(s) + 6CO(g)$~~ $\Delta H = -1.3KJ \times 6$

$2Fe_3O_4 + 2CO \rightarrow 6FeO + 2CO_2$ $\Delta H = \frac{-45.2}{2} = -22.6 kJ$

2

10. $2NO_2(g) \rightarrow N_2O_4(g)$

reverse ~~$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$~~ ~~$\Delta H = 339KJ$~~

$2NO_2 \rightarrow N_2 + 2O_2$ $\Delta H = -339 kJ$

reverse ~~$N_2O_4(g) \rightarrow N_2(g) + 2O_2(g)$~~ ~~$\Delta H = 48KJ$~~

$N_2 + 2O_2 \rightarrow N_2O_4$ $\Delta H = +48 kJ$

$\Delta H = -291 kJ$

11. $3Fe_2O_3(s) + CO(g) \rightarrow 2Fe_3O_4(s) + CO_2(g)$

~~$2Fe(s) + 3CO_2(g) \rightarrow Fe_2O_3(s) + 3CO(g)$ $\Delta H=1.8KJ$~~

~~$Fe_3O_4 + CO(g) \rightarrow 3FeO(s) + CO_2(g)$ $\Delta H=-1.4KJ$~~

~~$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$ $\Delta H=0.1KJ$~~

$3Fe_2O_3(s) + CO_2(g) \rightarrow Fe(s) + CO_2(g)$ $(\Delta H = -1.8KJ)9$ -16.2

$6FeO + 2CO_2 \rightarrow 2Fe_3O_4 + 2CO$ $(\Delta H = 1.4KJ)2$ 2.8

$6Fe + 6CO_2 \rightarrow 6FeO + 6CO$ $(\Delta H = -0.1KJ)6$ $-.6$

$3Fe_2O_3(s) + CO(s) \rightarrow 2Fe_3O_4 + CO_2(g)$ $\Delta H = -14\ KJ$

12. $H_2S(g) + 1/2O_2(g) \rightarrow S(s) + H_2O(l)$

$H_2S(g) + 3/2O_2(g) \rightarrow H_2SO_3(l)$ $\Delta H=-459KJ$

$H_2SO_3(l) \rightarrow H_2O(l) + SO_2(g)$ $\Delta H=139.5KJ$

$SO_2(g) \rightarrow S(s) + O_2(g)$ $\Delta H=668.3KJ$

$H_2S + 1/2\ O_2 \rightarrow H_2O + S$ $\Delta H = 348.8KJ$

13. $CO_2(g) \rightarrow C(s) + O_2(g)$

~~$H_2O(l) \rightarrow H_2(g) + 1/2O_2(g)$ $\Delta H=214.3KJ$~~

~~$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H=-667.9KJ$~~

~~$C(s) + 2H_2(g) \rightarrow CH_4(g)$ $\Delta H=-56.1KJ$~~

$CO_2 + 2H_2O \rightarrow CH_4 + 2O_2$ $\Delta H = +667.9KJ$

$CH_4 \rightarrow C + 2H_2$ $\Delta H = +56.1KJ$

$2H_2 + 2O_2 \rightarrow 2H_2O$ $(\Delta H = -214.3KJ)2$

$CO_2 \rightarrow C + O_2$ $\Delta H = 295.4\ KJ$

14. $N_2O_4(g) \rightarrow 2NO_2(g)$

$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ $\Delta H=339KJ$

$N_2O_4(g) \rightarrow N_2(g) + 2O_2(g)$ $\Delta H=-48KJ$

$N_2O_4 \rightarrow 2NO_2$ $\Delta H = 291\ KJ$

15. $CO_2 \rightarrow C(graphite) + O_2$

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2 + 4\ H_2O(l)$ $\Delta H=-5550KJ$

$H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$ $\Delta H=-712.5KJ$

missing C

16. $FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$

~~$2Fe(s) + 3CO_2(g) \rightarrow Fe_2O_3(s) + 3CO(g)$ $\Delta H = 17.2KJ$~~

~~$2Fe_3O_4(s) + CO_2(g) \rightarrow 3Fe_2O_3(s) + CO(g)$~~ $\Delta H = 29.2KJ$

~~$Fe_3O_4 + CO(g) \rightarrow 3FeO(s) + CO_2(g)$ $\Delta H = 13.5KJ$~~

$6FeO + 2CO_2 \rightarrow 2Fe_3O_4 + 2CO$ $(\Delta H = +13.5KJ)2$

$3Fe_2O_3 + CO \rightarrow 6Fe + CO_2$ $(\Delta H = -17.2KJ)3$

$6FeO + 6CO \rightarrow 6Fe + 6CO_2$ $\Delta H = 4.6KJ \div 6$ $\Delta H = .767KJ$

17. $H_2SO_3(l) \rightarrow H_2O(l) + SO_2(g)$

$H_2SO_3(l) \rightarrow H_2S(g) + 3/2O_2(g)$ $\Delta H = 1549KJ$

~~$SO_2(g) \rightarrow S(s) + O_2(g)$ $\Delta H = 2255.7KJ$~~

~~$S(s) + H_2O(l) \rightarrow H_2S(g) + 1/2O_2(g)$ $\Delta H = 1176.7KJ$~~

$H_2S + H_2O_2 \rightarrow S + H_2O$ $\Delta H = -1176.7KJ$

$S + O_2 \rightarrow SO_2$ $\Delta H = -2255.7KJ$

$H_2SO_3 \rightarrow H_2O + SO_2$ $\Delta H = -1883.4KJ$

18. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

~~$2NH_3(g) + 4H_2O(l) \rightarrow 2NO_2(g) + 7H_2(g)$ $\Delta H = 399KJ$~~

$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = 231KJ$

~~$4H_2(g) + 4O_2(g) \rightarrow 4H_2O(l)$~~ $(\Delta H = 122.4KJ)4$

$2NO_2 + 3H_2 \rightarrow 2NH_3 + 4H_2O$ $\Delta H = +399KJ$

$4H_2O \rightarrow 4H_2 + 4O_2$ $(\Delta H = -122.4KJ)4$

$N_2 + 3H_2 \rightarrow 2NH_3$ $\Delta H = -321.6KJ$