Chemistry 105, Chapter 8 Exercises

Internal Energy

1. Calculate ΔE for a gas that releases 38 J of heat and has 102 J of work done on it. *Ans. +64 J*

2. Calculate ΔE for a gas that absorbs 18 J of heat and has 13 J of work done on it. *Ans. 31 J*

3. Calculate ΔE for a gas that absorbs 20 J of heat and does 12 J of work by expanding. *Ans. 8 J*

4. Calculate q when a system does 54 J of work and its internal energy decreases by 72 J. *Ans. -18 J*

5. Calculate q when 72 J of work is done on a system and its internal energy increases by 61 J. *Ans. -11J*

Change in Enthalpy

6. NO(g) reacts with oxygen gas to give the brown gas NO_2. When one mole of NO(g) reacts with oxygen 57.0 kJ of heat is evolved.
   a. Write the thermochemical equation for the reaction between one mole of nitrogen oxide and oxygen.
   b. Is the reaction exothermic or endothermic?
   c. Draw an energy diagram for this reaction.
   d. What is ΔH when 5.00 g of NO reacts?
   e. How many grams of NO must react to release 10.0 kJ of heat?
   Ans.
   a. $NO(g) + 1/2O_2(g) \rightarrow NO_2(g)$ $\Delta H = -57.0$ kJ b. exothermic d. -9.50 kJ e. 5.26 g

7. Calcium carbide, CaC_2, is the raw material for the production of acetylene (used in welding torches). Calcium carbide is produced by reacting calcium oxide with carbon. Carbon monoxide is also produced in this reaction. When one mole of calcium carbide is formed 464.8 kJ is absorbed.
   a. Write a thermochemical equation for this reaction.
   b. Is the reaction exothermic or endothermic?
   c. Draw and energy diagram for this reaction.
   d. What is ΔH when 1.00 g of $CaC_2(s)$ is formed?
   e. How many grams of carbon must react to produce 3.03×10^3 kJ of heat?
   Ans.
   a. $CaO(s) + 3C(s) \rightarrow CaC2(s) + CO(g)$ $\Delta H = +464.8$ kJ b. endothermic d. +7.26 kJ e. 235. g

8. Calcium chloride is a compound frequently found in first aid hot packs. It gives off heat when dissolved in water. The following reaction takes place.

   $CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^-(aq)$ $\Delta H = -81.4$ kJ

   a. Calculate ΔH when one mole of calcium chloride precipitates from solution. *Ans.+81.4 kJ*
   b. What is ΔH when 1.00 g of calcium chloride precipitates from solution? *Ans. 0.733 kJ*

9. Consider the dissociation of water into ions.

   $H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$ $\Delta H = 55.8$ kJ

   a. Calculate ΔH when one mole of water is formed from the ions. *Ans.-55.8 kJ*
   b. What is ΔH when 1.00 g of water is formed? *Ans. -3.10 kJ*

10. Given,

    $2CuO(s) \rightarrow 2Cu(s) + O_2(g)$ $\Delta H^o = 314.6$ kJ

    a. determine the heat of formation of CuO, *Ans. -157.3 kJ/mole*
    b. calculate ΔH^o for the formation of 13.58 g of CuO. *Ans. -26.9 kJ*

11. Given,

    $2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2(g)$ $\Delta H^o = 3351.4$ kJ

    a. what is the heat of formation of $Al_2O_3(s)$, *Ans. -1675.7 kJ/mole*
    b. what is ΔH^o for the formation of 12.5 g of $Al_2O_3(s)$. *Ans. -205. kJ*

Specific Heat

12. Gold has a specific heat of 0.129 J/g^{o}C. If 5.00 g of gold absorbs 1.33 J of heat, what is the change in temperature of the gold? *Ans. 2.06^{o}C*

13. Titanium has a specific heat of 0.523 J/g^{o}C. If 5.88 g of titanium absorbs 4.78 J of heat, what is the change in temperature? *Ans. 1.55^{o}C*

14. When 5.00 g of chromium at 23.00 ^{o}C absorbs 62.5 J of heat, the temperature increases to 50.8^{o}C. What is the specific heat of chromium? *Ans. 0.450 J/g^{o}C*

15. The specific heat of aluminum is 0.902 J/g^{o}C. If an aluminum pie tin weighs 473. g how much heat will it absorb when heated from 23.00^{o}C to 375^{o}C in an oven? *Ans. 150 kJ*

16. How much heat is required to raise the temperature of 1 gallon of water (3600 g) from 0^{o}C to 45^{o}C? The specific heat for water is 4.184 J/g^{o}C. *Ans. 678 kJ*

Calorimetry

17. When 5.00 mL of ethyl ether, $C_4H_{10}O$, (d = 0.714 g/mL) is burned in a bomb calorimeter, the temperature rises from 23.5^{o}C to 39.7^{o}C. The calorimeter heat capacity is 10.34 kJ/^{o}C.
    a. Calculate the quantity of heat evolved. *Ans. -168. kJ*
    b. Calculate the heat of combustion per gram and per mole. *Ans. -46.9 kJ/g, -3.47 x 10^{3}kJ/mole,*

18. Fructose, $C_6H_{12}O_6$, is a sugar commonly found in fruit. A 4.50 g sample of fructose is burned in a bomb calorimeter. The heat capacity of the calorimeter is 2.115 x 10^{4}J/^{o}C. The temperature in the calorimeter rises from 23.49^{o}C to 27.71^{o}C.
    a. Calculate the quantity of heat evolved. *Ans. -89.3 kJ*
    b. Calculate the heat of combustion per gram and per mole. *Ans.-19.8 kJ/g, -3.57 x 10^{3}kJ/mole*

19. When a 3.88 g sample of $NH_4NO_3(s)$ dissolves in 60.0 g of water in a coffee-cup calorimeter, the temperature drops from 23.0°C to 18.4°C. Calculate ΔH for the solution process:

$NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq)$

Assume that the specific heat of the solution is the same as that of pure water (4.184 J/g°C). *Ans. +25.3 kJ*

20. When a 9.55 g sample of NaOH(s) dissolves in 100.0 g of water in a coffee-cup calorimeter, the temperature rises from 23.6°C to 47.4°C. Calculate ΔH for the solution process:

$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

Assume that the specific heat of the solution is the same as that of pure water (4.184 J/g°C). *Ans. -45.7 kJ*

Hess's Law

21. Given the following thermochemical equations,

$C_2H_2(g) + 5/2O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$ $\Delta H = -1299.5$ kJ
$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ kJ
$H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$ kJ

calculate the ΔH for the decomposition of one mole of acetylene to its elements in their stable state at 25°C and 1 atm. *Ans.-226.7 kJ*

$C_2H_2(g) \rightarrow 2C(s) + H_2(g)$

22. Given the following data,

$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$ $\Delta H^o = -534.2$ kJ
$H_2(g) + 1/2O_2 \rightarrow H_2O(g)$ $\Delta H^o = -241.8$ kJ

calculate the ΔH for the formation of $N_2H_4(l)$. *Ans.+50.6 kJ/mole*

$N_2(g) + 2H_2(g) \rightarrow N_2H_4(l)$

23. Given the following thermochemical equations,

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ $\Delta H = -571.6$ kJ
$N_2O_5(g) + H_2O(l) \rightarrow 2HNO_3(l)$ $\Delta H = -73.7$ kJ
$1/2N_2(g) + 3/2O_2(g) + 1/2H_2(g) \rightarrow HNO_3(l)$ $\Delta H = -174.1$ kJ

calculate the ΔH for the formation of $N_2O_5(g)$. *Ans.+11.3 kJ*

$N_2(g) + 5/2O_2(g) \rightarrow N_2O_5(g)$

Heats of Formation

ΔH_f^o's Data (KJ/mole) for Exercises 24-27:
$NH_3(g)$, -46.1; $NO(g)$, +90.2; $H_2O(g)$, -241.8; $H_2SO_4(l)$, -814.0; $SO_2(g)$, -296.8; $I^-(aq)$, -55.2; $Cl^-(aq)$, -167.2; $Cd^{2+}(aq)$, -75.9; $H_2O(l)$, -285.8; SO_4^{2-}, -909.3; H^+, 0.0

24. Using ΔH_f^o's calculate ΔH^o per mole of ammonia in the following reaction. Also, calculate ΔH^o per gram of ammonia. *Ans. -226.4 kJ/mole, -13.3 kJ/g*

    $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$
    ammonia

25. Using ΔH_f^o's calculate ΔH^o per mole of sulfuric acid in the following reaction. Also, calculate ΔH^o per gram of sulfuric acid. *Ans. +275.4 kJ/mole, +2.81 kJ/g*

    $2H_2SO_4(l) \rightarrow 2H_2O(g) + O_2(g) + 2SO_2(g)$

26. Using ΔH_f^o's calculate ΔH^o per mole of chlorine in the following reaction. Also, calculate ΔH^o per gram of chlorine. *Ans. -224.0 kJ*

    $Cl_2(g) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(s)$

27. Using ΔH_f^o's calculate ΔH^o for the following reaction. *Ans. +35.0 kJ*

    $Cd^{2+}(aq) + SO_2(g) + 2H_2O(l) \rightarrow SO_4^{2-}(aq) + 4H^+(aq) + Cd(s)$

28. Given the following data calculate ΔH_f^o for butane, $C_4H_{10}(g)$. *Ans. -124.7kJ/mole*

    $C_4H_{10}(g) + 13/2O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g)$ $\Delta H^o = -2658.3$ kJ
    ΔH_f^o $H_2O(g) = -241.8$ kJ/mol
    ΔH_f^o $CO_2(g) = -393.5$ kJ/mol

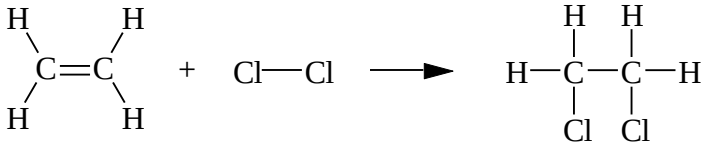
29. Given the following data calculate ΔH_f^o for calcium cyanamide, $CaCN_2(s)$. *Ans.-351.6 kJ/mole*

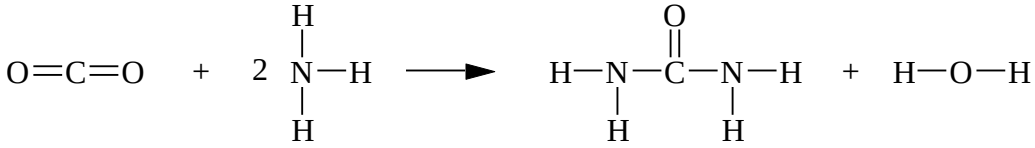
    $CaCO_3(s) + 2NH_3(g) \rightarrow CaCN_2(s) + 3H_2O(l)$ $\Delta H^o = +90.1$ kJ
    ΔH_f^o $CaCO_3(s) = -1206.9$ kJ/mol
    ΔH_f^o $NH_3(g) = -46.1$ kJ/mol
    ΔH_f^o $H_2O(l) = -285.8$ kJ/mol

30. Use bond energy values to estimate ΔH for the following reactions.

Average Bond Energies (KJ/mol)

C=C	614
C=O	745
C=O in CO_2	799 for each C=O
C-C	347
C-H	413
C-Cl	339
Cl-Cl	239
C-N	305
N-H	391
O-H	467

a. 

b. 

Ans.
a.-172 kJ
b. +91 kJ