Thermodynamics I
Chang, pp. 264-265
#15-38

15.) (a) since $P = 0$, $w = 0$

(b) $w = -P\Delta V = -0.80\,\text{atm}\left(\frac{101.3\text{ KPa}}{1\text{ atm}}\right)\cdot(\overbrace{5.4L - 1.6L}^{3.8L}) = 307.952\text{ L}\cdot\text{KPa}$

-310 J

(c) $w = -P\Delta V = -3.7\,\text{atm}\left(\frac{101.3\text{ KPa}}{1\text{ atm}}\right)\cdot 3.8L = 1424.278\text{ L}\cdot\text{KPa}$

-1400 J

16.) (a) since $P = 0$, $w = 0$

(b) $w = -P\Delta V = -1.5\,\text{atm}\left(\frac{101.3\text{ KPa}}{1\text{ atm}}\right)\cdot(\overbrace{0.0893L - 0.0267L}^{0.0626L})$

$= 9.51207\text{ L}\cdot\text{KPa} = $ **-9.5 J**

17.) $\Delta E = q + w = +127J - 325J = $ **-198 J**

18.) $\Delta E = q + w = -26J + 74J = $ **+48 J**

19.) $50.0\text{g Sn} \times \frac{1\text{mol}}{118.71\text{g}} \times \frac{1\ H_2}{1\text{ Sn}} = 0.4211945076$ mol H_2

$V = \frac{nRT}{P} = \frac{(0.4211945076\text{ mol})(0.08206\frac{L\cdot atm}{mol\cdot K})(298K)}{(1.00\text{ atm})}$

$= 10.29983995\text{ L}$

$w = -P\Delta V$

$= -1.00\,\text{atm}\left(\frac{101.3\text{ KPa}}{1\text{ atm}}\right)\cdot 10.3L$

$= 1043.373787\text{ KPa}\cdot\text{L}$

1040 J

20.) $V = \frac{nRT}{P} = \frac{(1.0\text{ mol})(0.08206\frac{L\cdot atm}{mol\cdot K})(373K)}{(1.0\text{ atm})} = 30.60838L$

$w = -P\Delta V = -(1.0\text{ atm})\left(\frac{101.3\text{ KPa}}{1\text{ atm}}\right)\cdot 30.6\text{ L}$

$= -3100.628894\text{ L}\cdot\text{KPa} = $ **-3100 J**

21. Enthalpy – changes in heat at a constant pressure.
Enthalpy of Reaction – difference in enthalpies of products & reactants.
→ ($\Delta H_{RXN} = \Sigma \Delta H_f^\circ(PROD) - \Sigma \Delta H_f^\circ(REACT)$)
Heat of Reaction and Enthalpy of Reaction are the same if the reaction occurs at constant pressure

22. The energy change which accompanies the formation of a particular substance is different for different physical states of that substance. For example, water is one of the products of the combustion of a hydrocarbon. Usually, water is produced in the form of steam and releases 241.8 KJ* for each mole of steam produced. When steam condenses to liquid water, more energy is released. As a result, if combustion produces LIQUID water, it releases 285.8 KJ* per mole of water formed. *(Values from Chang, Appendix 3). Also, if solids & liquids become gases, work is done.

23. When 4 moles of ammonia gas react with 5 moles of oxygen gas, 904 KJ of energy are released (exothermic) along with the production of 4 moles of liquid water and 6 moles of steam.

24. (a) ΔH is doubled (b) ΔH changes from − to +
(c) ΔH is a little less negative

25. $\frac{-879\ KJ}{\text{mol reaction}} \times \frac{1\ \text{mol reaction}}{2\ ZnS\ \text{mol}} \times \frac{1\ mol}{97.45\ g} = $ **4.51 KJ/g evolved**

26. $1.26 \times 10^4\ g\ NO_2 \times \frac{1\ mol}{46.01\ g} \times \frac{114.6\ KJ}{2\ mol\ NO_2} = 15691.80613\ KJ$
15700 KJ

27. $q = 2\text{ moles } H_2O \times \frac{483.6\text{ KJ}}{2\text{ mol } H_2O} = +483.6\text{ KJ}$

$w = -P\cdot\Delta V = -\left[(1.0\text{ atm})\cdot\left(\frac{101.3\text{ KPa}}{1.0\text{ atm}}\right)\right]\cdot 32.65988\text{ L}$

$V_{new} = \frac{nRT}{P} = \frac{(3\text{ mol})(0.08206\frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(398\text{ K})}{(1.0\text{ atm})} = 97.97964\text{ L}$

$V_{orig.} = \frac{(2\text{ mol})(0.08206\frac{\text{L atm}}{\text{mol K}})(398\text{ K})}{(1.0\text{ atm})} = 65.31976$

$\Delta V = 97.97964\text{ L} - 65.31976\text{ L} = 32.65988\text{ L}$

NOTE: ΔV can be calculated this way or with less math by using Δn in the ideal gas eqn.

$w = -3308.445844\text{ J}$ -3300 J or -3.3 KJ

$\Delta U = +483.6\text{ KJ} + \left(-3308.445844\text{ J} \times \frac{1\text{ KJ}}{1000\text{ J}}\right)$
$= 480.2915542\text{ KJ}$
$= +480\text{ KJ}$

28. $w = 0$ because you are replacing 3 mol $H_2(g)$ and 3 mol $Cl_2(g)$ with 6 mol $HCl(g)$. Since you start with 6 mol of gas, total, and end with 6 mol of gas at the same T & P, the ΔV will be ZERO.

$q = -184.6\frac{\text{KJ}}{\text{mol}} \times 3\text{ mol} = -553.8\text{ KJ}$

$\Delta U = q + w = -553.8\text{ KJ} + 0\text{ KJ} = -553.8\text{ KJ}$

29. Specific heat applies to a particular substance and is a per gram quantity. Heat capacity applies to a particular <u>OBJECT</u> such as a calorimeter and has the amount (mass) already factored in.

specific heat = J/g C° ← intensive   heat capacity = J/C° ← extensive

30. Calorimetry - any of several techniques used to measure changes in thermal energy. While most of the energy transfer typically is absorbed by the <u>CONTENTS</u> of the calorimeter, some of the energy is absorbed by the structure of the calorimeter. Knowing the heat capacity of the calorimeter allows us to account for the heat which is not absorbed by the contents of the calorimeter. Heat capacity of a calorimeter is determined experimentally by conducting heat transfers in the calorimeter and dividing the difference between heat lost and heat gained by the change in temperature of the calorimeter.

TWO TYPES of CALORIMETER:

① Constant Pressure (Coffee cup) Calorimeter - insulated container, not air tight, measures heat changes, but work is unknown. (because $\Delta V = ?$)

② Constant Volume (Bomb) Calorimeter - rigid steel container with ignition wires, surrounded by a container of water. Measures heat and forces $w = 0$ by making $\Delta V = 0$

31. (d) Heat will flow from Cu to Al because Cu is at a higher temperature. Cu atoms will bump into Al atoms. As a result of the collisions, Al atoms will (on average) speed up and Cu atoms will (on average) slow down until both metals reach the same average kinetic energy.

32. $c = J/gC°$ $\quad C = J/C°$

$$c = \frac{C}{m} = \frac{85.7\ J/C°}{362\,g} = 0.2367403315\ J/gC°$$

SPECIFIC HEAT CAPACITIES p. 247 $\quad$ (0.237 J/gC°)

33. $q = mc\Delta t = (6220\,g)(0.385\ J/gC°)(\cancel{324.3°C - 20.5°C})$ $\quad 303.8\ C°$

$= 727509.86\ J$

$= 728\ kJ$

34. $q = mc\Delta t = (366\,g)(0.139\ J/gC°)(\cancel{77.0°C - 12.0°C})$ $\quad 65.0\ C°$

$= 3306.81\ J = 3.31\ kJ$

35. $q_{lost} = q_{gained}$

$mc\Delta t\,(Fe) = mc\Delta t\,(Au)$

$(20.0\,g)(0.444\ J/gC°)(55.6°C - x) = (10.0\,g)(0.129\ J/gC°)(x - 18.0°C)$

$493.728\ J - 8.88\ J/C°\,x = 1.29\ J/C°\,x - 23.22\ J$

$493.728\ J + 23.22\ J = 1.29\ J/C°\,x + 8.88\ J/C°\,x$ $\quad 50.83067847\ °C$

$516.948\ J = 10.17\ J/C°\,x$ $\quad x = \frac{516.948\ J}{10.17\ J/C°} = 50.83°C$

50.8°C

36. $q_{lost\,Al} = q_{gained\,H_2O}$

$mc\Delta t_{(Al)} = mc\Delta t_{(H_2O)}$

$(12.1\,g)(0.900\,J/gC°)(\cancel{81.7°C - 24.9°C})$ [56.8 C°] $= m\,(4.184\,J/gC°)(\cancel{24.9°C - 23.4°C})$ [1.5 C°]

$618.552\,J = 6.276\,J/g \cdot m$

$m = \frac{618.552\,J}{6.276\,J/g} = 98.5583174\,g$

98.6 g

37. $q = C\Delta t = 3024\,J/C° \cdot 1.126\,C°$

$= 3405.024\,J$

$\frac{3405.024\,J}{0.1375\,g} = 24763.81091\,J/g \cdot \frac{24.31\,g}{mol} = 602008.2432\,J/mol$

24.8 KJ/g **602 KJ/mol**

38. $HCl + KOH \rightarrow H_2O + KCl \quad \Delta H_{Rxn} = -56.2\,KJ/mol$

HCl: 85.0 mL, 0.900 M; KOH: 85.0 mL, 0.900 M

$n = (0.0850\,L)(0.900\,\frac{mol}{L}) = 0.0765\,mol\ HCl$

$0.0765\,mol\ KOH$

$q = (-56.2\,KJ/mol)(0.0765\,mol) = -4.2993\,KJ$ or

4.2993 KJ released

$q = mc\Delta t + C\Delta t$

$4299.3\,J = (\cancel{85.0\,mL + 85.0\,mL}$ [170. mL]$)(1.00\,g/mL)(4.184\,J/gC°)\,\Delta t + C\Delta t$ [(325 J/C°)]

$4299.3\,J = 711.28\,J/C° \cdot \Delta t + 325\,J/C° \cdot \Delta t$

$4299.3\,J = 1036.28\,J/C°\ \Delta t$

$\Delta t = \frac{4299.3\,J}{1036.28\,J/C°} = 4.148782182\,C°$

$t_f = t_i + \Delta t = 18.24°C + 4.15°C =$ **22.39°C**