Thermodynamics Unit - Internal Energy, Work and Heat

1. The internal energy of a system increased by 982 J when it absorbed 492 J of heat. Was work done by or on the system? How much work was done? What is ΔV if pressure is constant at 1 atm?

$\Delta U = +982J$ $(increased\ means+)$

$q = +492J$ $(absorbed\ means+)$

$\Delta U = q + w$

$w = \Delta U - q$

$w = 982J - 492J = +490J$ $(+means\ work\ done\ ON\ system)$

$Convert\ J\ to\ L*atm:$

$w = 490Jx(\dfrac{1L*atm}{101.325J}) = 4.836L*atm$

$w = -P\Delta V$

$\Delta V = -\dfrac{w}{P} = -\dfrac{4.836L*atm}{1atm} = -4.836L(-means\ system\ was\ compressed)$

2. A gas in a cylinder was placed in a heater and gained 5500 kJ of heat. If the cylinder increased in volume from 345 mL to 1846 mL against an atmospheric pressure of 750 Torr during the process, what is the change in internal energy of the gas in the cylinder?

$q = +5500J$ $(gained\ means+)$

$P = 750Torr(\dfrac{1atm}{760Torr}) = 0.987atm$

$w = -P\Delta V$

$w = -0.987atm(1.846L - 0.345L) = -1.481L \bullet atm(\dfrac{101.325J}{1atm}) = -150.11J = -0.15011kJ$

$\Delta U = w + q$

$\Delta U = 5500kJ - 0.15011kJ = +5499.85kJ(+means\ system\ increased\ in\ internal\ energy)$

3. The change in internal energy for the combustion of 1.00 mol $CH_4(g)$ in a cylinder according to the reaction $CH_4(g) + 2\ O_2(g) \rightarrow CO_2\ (g) + 2\ H_2O(g)$ is -892.4 kJ. If a piston connected to the cylinder performs 492 kJ of expansion work due to the combustion, how much heat is lost from the system? What is this system in this situation?

The system is the reaction (reactants to products). The air and cylinder are the surroundings.

$\Delta U = -892.4 kJ$ (*−means system decreased in internal energy*)

$w = -492 kJ$ (*work done BY system means −*)

$\Delta U = w + q$

$q = \Delta U - w$

$q = -892.4 kJ -^- 492 kJ = -400.4 kJ$ (*−means system released/lost heat*)

4. A 80W electric heater (1W = 1J/s) operates for 7.5 minutes to heat the gas in a cylinder. At the same time, the gas expands from 5 to 11 L against a constant atmospheric pressure of 2.78 atm. What is the change in internal energy of the gas?

$q = power \times time$

$q = (80\frac{J}{s})(7.5\,min(\frac{60\,sec}{1\,min})) = 36000J = 36kJ$

$w = -P\Delta V$

$w = -(2.78atm)(11L - 5L) = -16.68L \bullet atm(\frac{101.325J}{1L \bullet atm}) = -1690J = -1.69kJ$

$\Delta U = q + w$

$\Delta U = 36kJ - 1.69kJ = 34.31kJ$ (*system increased in internal energy*)

5. For which of the following reactions at room temperature (25 ˚C) would there be 5.0 kJ of work done on the system?

a. 2 $H_2O(l)$ + $O_2(g)$ → 2 $H_2O_2(l)$ $\qquad$ Δn_{gas}=(0-1)=-1

b. $CO_2(g)$ + 2 $H_2O(g)$ → $CH_4(g)$ + 2 $O_2(g)$ $\qquad$ Δn_{gas}=(3-3)=0

c. $N_2H_2(g)$ + $CH_3OH(g)$ → $CH_2O(g)$ + $N_2(g)$ + 2 $H_2(g)$ $\qquad$ Δn_{gas}=(4-2)=2

d. CH2O(g) + N2(g) +2 H2(g) → N2H2(g) + CH3OH(g)Δn_{gas}=(2-4)=-2

e. $CH_4(g)$ + 2 $O_2(g)$ → $CO_2(g)$ + 2 $H_2O(g)$ $\qquad$ Δn_{gas}=(3-3)=0
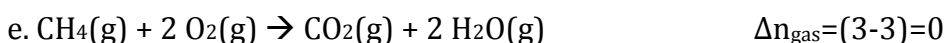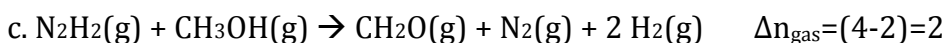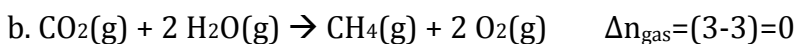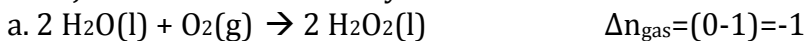
How did we know we were looking for a Δn_{gas} of -2?
Work done ON the system is positive (+5kJ) and the gas should be compressed (-ΔV)

$w = -P\Delta V = -\Delta n_{gas}RT$

$\Delta n_{gas} = -\frac{w}{RT}$

$\Delta n_{gas} = -\frac{5kJ}{(0.008314\frac{kJ}{molK})(298K)} \approx -2mol$

6. If an MP3 player does 200 KJ of work and released 100 kJ of heat, what is the

change in internal energy for the MP3 player?

$$system = mp3 \quad player$$

$$w = -200kJ \quad (- \quad because \quad work \quad done \quad BY \quad system)$$

$$q = -100kJ \quad (- \quad because \quad heat \quad released \quad by \quad system)$$

$$\Delta U = q + w$$

$$\Delta U = -100kJ - 200kJ = -300kJ$$

7. In the formula ΔU = q + w, work done by the system during expansion is __negative_ (positive/negative), and heat ___gained__ (gained/lost) by the system is positive.

8. The pressure-volume work done by an ideal gaseous system at constant volume is ___0___?