First Law of Thermodynamics

Constants and Conversion Factors

1 Pa	1 N m^{-2}, 1 kg m^{-1} s^{-2}
1 bar	10^5 Pa
1 atm	101.325 kPa
Torr	101325/760 = 133.32 Pa
1 mmHg	133.32 Pa
1 psi	6.894 kPa
1 liter	1000.028 cm
1 atm	1.01325 x 10^6 dynes cm^{-1}
1 cal	4.1833 joules
1 volt-coulombs	1 joules
	0.01 liter-atm
	10 cc-atm
1 liter-atm	1.0133 x 10^9 ergs
	1.0133 x 10^9 joules
	24.218 cal
1 cc-atm	0.024212 cal
Molar volume of ideal gas at 0 °C and 1 atm	22.4140 liter $mole^{-1}$
Ice Point	273.16 K
Molar gas constant (R)	8.3144 joules K^{-1} $mole^{-1}$
	1.9872 cal K^{-1} $mole^{-1}$
	0.082054 liter-atm. K^{-1} $mole^{-1}$
	82.057 cc.-atm. K^{-1} $mole^{-1}$
Avogadro number (N)	6.0228 x 10 $mole^{-1}$
Boltzmann constant (k = R/N)	1.3805 x 10^{-16} erg K^{-1}
Planck constant (h)	6.6242 x 10^{-27} erg sec
6.6242 x 10^{-34} joules sec	
Velocity of light (c)	2.99776 x 10^{10} cm sec^{-2}
Faraday (F)	96,500 coulombs mol^{-1}
	23,070 cal. $volt^{-1}$ mol^{-1}

Problems

1. A substance expands by 1 liter against a constant pressure of 1 atm. Calculate the work done in (a) liter-atm., (b) newton-meter, (c) ergs, (d) joules, (e) calories.

2. A quantity of 50 coulombs of electricity flows through a conductor under the influence of a potential of 2 volts. Calculate the energy expenditure in (a) joules, (b) ergs, (c) calories.

3. The specific volume of liquid acetic acid exceeds that of the solid at the melting point by 0.1595 cc g^{-1} at 1 atm pressure. Determine the work of expansion, in calories, and in joules accompanying the fusion of 2 mole of acetic acid at atmospheric pressure.

4. Calculate the work done against a constant pressure of 700.0 mm when 1 mole of water evaporates completely at 100 ^{o}C; the specific volume of water is approximately 1 cc g^{-1} and that of the vapor is 1720 cc g^{-1}. Express the results in (i) ergs, (ii) liter-atm., (iii) joules, (iv) N-m, (v) cal.

5. The density of mercury at 0 ^{o}C and 1 atm pressure is 13.595 g cc^{-1}. Determine the work of expansion in ergs when the temperature of 100 g of mercury is raised from to 100 ^{o}C at 1 atm pressure. Given that the mean specific heat in this range is 0.0330 cal deg^{-1} g^{-1}, what proportion of the total amount of heat supplied to the mercury is the work of expansion?

6. The faraday is usually given as 96,488 coulombs per mol; show that it is also equal to 23,070 cal $volt^{-1}$ mol^{-1}, and that the quantity 23,070 cal $volt^{-1}$ mol^{-1} $faraday^{-1}$ is dimensionless and equal to unity.

7. If an electric motor produces 10 kJ of energy per second as work and dispenses 2 kJ of energy as heat to the surroundings. Calculate the change in internal energy of the electric motor per second.

8. A spring is wound by investing 50 kJ of energy as mechanical work and during that process 5 kJ of energy was lost to the surrounding as heat. Calculate the change in internal energy of the spring.

9. Calculate the work done when 100 g of calcium carbonate dissociates completely into calcium oxide and carbon dioxide (a) in a closed vessel of constant volume, (b) in vacuum and (c) in an open beaker at 25 ^{o}C.

10. Calculate the work done when 58 g of gaseous butane burns completely in the presence of oxygen in an open atmosphere. Express your result as a function of T.

11. Calculate the difference in the change in enthalpy and the change in internal energy of one mole of Sn(s, grey) of densities 5.75 g cc-1 converts in to Sn(s, white) of density 7.31 g cc-1 at 10 bar pressure at 298 K.

12. Calculate the difference in the change in enthalpy and the change in internal energy of one mole of C(s, graphite) of densities **2.26** g cc-1 converts in to C(s, diamond) of density **3.51** g cc-1 at 1000 bar pressure at 1500 K.

13. Water is heated to boiling through an electric heater in thermal contact with it. A current of 1 A from a supply of 12 V is passed for 2.5 min, under a pressure of 1.0 atm. It was observed that 800 mg of water is vaporized. Calculate the change in molar enthalpy and change in molar internal energy during evaporation. [40.5 kJ mol^{-1}, 37.5 kJ mol^{-1}]

14. The boiling point and molar enthalpy of vaporization of benzene are 80 ^oC and 30.8 kJ mol^{-1} . In order to vaporize 10 g of benzene, how long it would require to supply a current of 0.5 A from a 12 V source? Calculate the change in molar internal energy. [27.9 kJ mol^{-1}, 660 s]

15. The Debye extrapolation provides the dependability of the heat capacity for a solid at extremely low temperature which can be written as $Cp = aT^3$. A sample of solid is heated from a temperature close to 0 K to a temperature T, calculate the change in enthalpy.

16. Calculate the difference between final pressures of a sample of argon (g = 5/3) at 200 kPa expands in an isothermal reversible and in a reversible adiabatic processes to thrice of its initial volume.

17. From the equation of state PV = nRT for an ideal gas, show that the volume expansivity is equal to 1/T and isothermal compressibility is equal to 1/P.

18. A reaction occurs in a vessel fitted with a movable piston of cross-sectional area 40 cm^2. After completion of reaction, the piston is driven outwardly by 10 cm against an external pressure of 100 kPa. Calculate the work done by the system.

19. A sample of gas Ar expands isothermally at 0 ^oC to double of its volume (a) freely, against zero external pressure (b) reversibly and (c) against a constant external pressure which may be treated as equivalent to the final pressure of the gas. For three processes calculate q, w, ΔU and ΔH.

20. Calculate the final pressure, q, w and ΔU for a one mole of a monatomic perfect gas initially at 1.0 atm and 300 K, when heated to a temperature of 400 K at constant volume.

21. At 37 ^{o}C, a sample of 6.0 g of ethane gas occupies a volume of 15 dm^{3}. Calculate the work done when the gas expands isothermally (a) against a constant external pressure of 500 torr until its volume has increased by 4.5 dm^{3}. (b) If the expansion has occurred reversibly.

22. When a sample of helium (for which γ = 3R/2) at 100 kPa expands reversibly and adiabatically to thrice of its initial volume. Calculate the final pressure.

23. The expression C_p /(J K−1) = 20.17 + 0.3665(T/K) show the variation of constant-pressure heat capacity of a sample of a perfect gas with temperature. The temperature of the sample was raised from 25 to 200 oC (a) at constant pressure (b) at constant volume, calculate the q, w, ΔU, and ΔH.

24. 12 g of a sample of argon expands reversibly and adiabatically from 1 to 3 dm3 at 0 oC, calculate the final pressure of the sample.

25. A sample of 4.4 g carbon dioxide of undergoes reversible adiabatic expansion at 300 K from a volume of 500 cc to 3.0 dm3. Calculate the work done by the gas.

26. An increase in the temperature of a sample of 3.0 mol argon (gas) was found to be of 3 k when 277 J of energy was supplied as heat. Calculate the molar heat capacities of the gas at constant pressure and constant volume.

27. Calculate q, ΔU and ΔH, when a sample of a 2.0 mol of carbon dioxide is heated from 240 to 280 K at a constant pressure of 1.25 atm. Given that C_{p,CO_2} = 37.11 J K^{-1} mol^{-1}.

28. A fall of 10 K temperature was observed when a vapor at 25 atm and 278 K is allowed to expand to a final pressure of 1.0 atm adiabatically. Calculate the J-T coefficient, μ at 278 K. assuming that μ does not vary in this temperature range.

29. The volume of a particular liquid depends on temperature as $V_T = V_0\{0.77 + 3.7 \times 10^{-4} (T\text{-}298) + 1.52 \times 10^{-6} (T\text{-}298)^2\}$, where V_o is the volume at 298 K. Calculate the co-efficient of expansion, α at 320 K.

30. Calculate the pressure that needs to be applied in order to increase the density of lead by 0.08 percent if its isothermal compressibility at 293 K is 2.21 x 10^{-6} atm^{-1}.

GOOD LUCK

NOTE: Sources: P. W. Atkins, Glasstone, Laidler & Meiser