Extra Problem Set 1: Ideal gases, heat capacity, enthalpy, entropy

1. To what temperature must a 1.0 l sample of a perfect gas be cooled from 25°C in order to reduce its volume to 100 cm^3 at constant pressure?

2. To what temperature must a sample of a perfect gas of volume 500 ml be cooled from 35°C in order to reduce its volume to 150 cm^3 at constant pressure?

3. At 500°C and 699 Torr, the mass density of sulfur vapor is 3.71 g/l. What is the molecular formula of sulfur under these conditions? Assume the vapor behaves as an ideal gas under these conditions.

4. A perfect gas undergoes isothermal compression, which reduces its volume by 2.20 l (be careful here. make sure you interpret this sentence properly). The final pressure and volume of the gas are 3.78×10^3 Torr and 4.65 l respectively. Calculate the original pressure of the gas in (a) Torr, (b) atm

5. A chemical reaction takes place in a container of cross-sectional area 100 cm2. As a result of the reaction, a piston is pushed out through 10 cm against an external pressure of 1.0 atm. Calculate the work done by the system.

6. A chemical reaction takes place in a container of cross-sectional area 50.0 cm2. As a result of the reaction, a piston is pushed out through 15 cm against an external pressure of 121 kPa. Calculate the work done by the system.

7. A sample consisting of 1.0 mol of a monoatomic perfect gas is expanded reversibly and isothermally at 0°C from 22.4 l to 44.8 l. Calculate Δq, Δw, ΔU and ΔH.

8. A sample consisting of 2.0 mol of a perfect gas is expanded reversibly and isothermally at 22°C from 22.8 l to 31.7 l. Calculate Δq, Δw, ΔU and ΔH.

9. A sample consisting of 1.0 mol of a perfect gas is expanded isothermally at 0°C against a constant external pressure equal to the final pressure of the gas from 22.4 l to 44.8 l. Calculate Δq, Δw, ΔU and ΔH.

10. A sample consisting of 2.0 mol of a perfect gas is expanded isothermally at 22°C against a constant external pressure equal to the final pressure of the gas from 22.8 l to 31.7 l. Calculate Δq, Δw, ΔU and ΔH.

11. A sample consisting of 1.0 mol of a perfect gas is expanded isothermally at 0°C against zero external pressure from 22.4 l to 44.8 l. Calculate Δq, Δw, ΔU and ΔH.

12. A sample consisting of 2.0 mol of a perfect gas is expanded isothermally at 0°C against zero external pressure from 22.8 l to 31.7 l. Calculate Δq, Δw, ΔU and ΔH.

13. A 1.0 mole sample of a monoatomic perfect gas at 1.0 atm and 300 K is heated reversibly to 400 K at constant volume. Calculate the final pressure, ΔU, Δq and Δw.

14. A 2.0 mole sample of a perfect gas, for which the heat capacity at constant volume is 5/2 nR, at 111 kPa and 277 K is heated reversibly to 356 K at constant volume. Calculate the final pressure, ΔU, Δq and Δw.

15. A sample of 4.50 g of methane gas occupies 12.7 l at 310 K. Calculate the work done when the gas (assume it behaves as an ideal gas) expands isothermally against a constant external pressure of

200 Torr until its volume has been increased by 3.3 l (be careful here. make sure you interpret the last sentence properly).

16. A sample of 6.56 g of argon gas occupies 18.5 l at 305 K. Calculate the work done when the gas (assume it behaves as an ideal gas) expands isothermally against a constant external pressure of 7.7 kPa until its volume has been increased by 2.5 l (be careful here. make sure you interpret the last sentence properly).

17. A sample of 4.50 g of methane gas occupies 12.7 l at 310 K. Calculate the work done when the gas (assume it behaves as an ideal gas) expands isothermally and reversibly until its volume has been increased by 3.3 l (be careful here. make sure you interpret the last sentence properly).

18. A sample of 6.56 g of argon gas occupies 18.5 l at 305 K. Calculate the work done when the gas (assume it behaves as an ideal gas) expands isothermally and reversibly until its volume has been increased by 2.5 l (be careful here. make sure you interpret the last sentence properly).

19. A sample of 1.00 mol water vapor is condensed isothermally to liquid water at 100°C and a constant pressure of 1 atm. The standard enthalpy of vaporization of water at 100°C is 40.656 kJ/mol. Find Δw, Δq and ΔH for this process, assuming water vapor behaves as an ideal gas.

20. A sample of 2.00 mol methane gas is condensed isothermally to liquid methane at 64°C and a constant pressure of 1 atm. The standard enthalpy of vaporization of methane at 64°C is 35.3 kJ/mol. Find Δw, Δq and ΔH for this process, assuming methane gas behaves as an ideal gas. Assume that the volume of liquid methane is much smaller than methane gas.

21. When 229 J of energy is supplied as heat at constant pressure to 3.0 mol of an ideal gas, the temperature of the sample increases by 2.55 K. Calculate the molar heat capacity at constant pressure of the gas. Calculate the molar heat capacity at constant volume of the gas.

22. When 178 J of energy is supplied as heat at constant pressure to 1.9 mol of an ideal gas, the temperature of the sample increases by 1.78 K. Calculate the molar heat capacity at constant pressure of the gas. Calculate the molar heat capacity at constant volume of the gas.

23. A sample consisting of 3.0 mol of an ideal gas at 200 K and 2.00 atm is compressed reversibly and adiabatically until the temperature reaches 250 K. Given that its molar constant-volume heat capacity is 27.5 J K^{-1} mol^{-1}, calculate Δq, ΔU, Δw, ΔH.

24. A sample consisting of 2.5 mol of an ideal gas at 220 K and 200 kPa is compressed reversibly and adiabatically until the temperature reaches 255 K. Given that its molar constant-volume heat capacity is 27.6 J K^{-1} mol^{-1}, calculate Δq, ΔU, Δw, ΔH.

25. Calculate the change in entropy when 25 kJ of energy is transferred reversibly and isothermally as heat to a large block of iron at 0°C.

26. Calculate the change in entropy when 25 kJ of energy is transferred reversibly and isothermally as heat to a large block of iron at 100°C.

27. Calculate the molar entropy of a constant-volume sample of a monoatomic ideal gas at 500 K given that it is 146.22 J K^{-1} mol^{-1} at 298 K. Hint: since you are given the molar entropy at one temperature and want to calculate it at another temperature, you probably need to know $\left(\frac{\partial S}{\partial T}\right)_V$, a

quantity that was calculated in Problem Set 9. Once you know $\left(\frac{\partial S}{\partial T}\right)_V$, you should be able to determine ΔS for a given ΔT.

28. A system undergoes a process in which the entropy change is +2.41 J/K. During the process, 1.00 kJ of heat is added to the system at 500 K. Is this process thermodynamically reversible? Explain your reasoning.

29. A sample of methane gas of mass 25 g at 250 K and 18.5 atm expands isothermally and reversibly until its presure is 2.5 atm. Calculate the change in entropy of the gas, assuming that it behaves as an ideal gas.

30. A sample of nitrogen gas of mass 35 g at 230 K and 21.1 atm expands isothermally and reversibly until its presure is 4.3 atm. Calculate the change in entropy of the gas, assuming that it behaves as an ideal gas.

31. A sample of a perfect gas that initially occupies 15 l at 250 K and 1.00 atm is compressed isothermally. To what volume must the gas be compressed to reduce its entropy by 5.0 J/K?

32. A sample of a perfect gas that initially occupies 11.0 l at 270 K and 1.20 atm is compressed isothermally. To what volume must the gas be compressed to reduce its entropy by 3.0 J/K?

Answers:

1. 29.8 K
2. 92.4 K
3. S_8
4. (a) 2566 Torr (b) 3.38 atm
5. -101 J
6. -90.75 J
7. $\Delta q = +1.57$ kJ, $\Delta w = -1.57$ kJ, $\Delta U = 0$, $\Delta H = 0$
8. $\Delta q = +1.62$ kJ, $\Delta w = -1.62$ kJ, $\Delta U = 0$, $\Delta H = 0$
9. $\Delta q = +1.13$ kJ, $\Delta w = -1.13$ kJ, $\Delta U = 0$, $\Delta H = 0$
10. $\Delta q = +1.38$ kJ, $\Delta w = -1.38$ kJ, $\Delta U = 0$, $\Delta H = 0$
11. $\Delta q = 0$, $\Delta w = 0$, $\Delta U = 0$, $\Delta H = 0$
12. $\Delta q = 0$, $\Delta w = 0$, $\Delta U = 0$, $\Delta H = 0$
13. $P_f = 1.33$ atm, $\Delta U = 1.25$ kJ, $\Delta w = 0$, $\Delta q = +1.25$ kJ
14. $P_f = 143$ Pa, $\Delta U = 3.28$ kJ, $\Delta w = 0$, $\Delta q = +3.28$ kJ
15. $\Delta w = -88$ J
16. $\Delta w = -19.3$ J
17. $\Delta w = -167$ J
18. $\Delta w = -52.7$ J
19. $\Delta w = +3.10$ kJ, $\Delta q = -40.656$ kJ, $\Delta H = -40.656$ kJ
20. $\Delta w = +5.60$ kJ, $\Delta q = -70.6$ kJ, $\Delta H = -70.6$ kJ
21. $C_{p,m} = 30$ J K^{-1} mol^{-1}, $C_{v,m} = 21.7$ J K^{-1} mol^{-1}
22. $C_{p,m} = 52.6$ J K^{-1} mol^{-1}, $C_{v,m} = 44.3$ J K^{-1} mol^{-1}
23. $\Delta q = 0$, $\Delta U = +4.1$ kJ, $\Delta w = +4.1$ kJ, $\Delta H = +5.4$ kJ
24. $\Delta q = 0$, $\Delta U = +2.4$ kJ, $\Delta w = +2.4$ kJ, $\Delta H = +3.1$ kJ
25. $\Delta S = 91.5$ J K^{-1}
26. $\Delta S = 67$ J K^{-1}
27. $S_m(500\text{ K}) = 152.67$ J K^{-1} mol^{-1}
28. No, because $q_{rev} = 1.21$ kJ $\neq 1.00$ kJ. $q_{rev} = q$ for reversible process. Calculate q_{rev} from $\Delta S = \Delta q_{rev}/T$
29. $\Delta S = +25.9$ J/K
30. $\Delta S = +16.5$ J/K
31. $V_f = 6.6$ l
32. $V_f = 6.0$ l