Question 1  [40 points; 20 points each]

(a) Suppose that 10.0 mol of \( \text{C}_2\text{H}_6(g) \) is confined to 4.860 dm\(^3\) at 27\(^0\)C. Predict the pressure exerted by this gas from the (a) perfect gas and (b) van der Waals equation of state. Calculate the compression factors in both a and b.

For ethane: 
\[ a = 5.562 \text{ L}^2 \text{ atm mol}^{-2}; \quad b = 6.380 \times 10^{-2} \text{ L mol}^{-1}. \]
(b) 2 moles of Helium were expanded isothermally at 22 °C from 22.4 dm$^3$ to 44.8 dm$^3$ (a) reversibly (b) against a constant external pressure, $P_{ext}$, equal to the final pressure of the gas, and (c) freely (against zero external pressure). For the three processes, calculate $q$, $w$, $ΔU$ and $ΔH$. 
Question 2  [30 points; 3 points each]
Briefly define the following terms.

(a) virial coefficients

(b) Boyle temperature

(c) first law of thermodynamics

(d) zeroth law of thermodynamics

(e) Dalton’s law of partial pressures
(f) work

(g) van der Waals loops

(h) Maxwell construction

(i) mathematical representation of Kirchoff’s law

(j) internal pressure
Question 3  [30 points; 10 points each]
(a) If \( c = \frac{C_{v,ir}}{R} \), prove that in an adiabatic expansion

\[
T_f = T_i \left( \frac{v_i}{v_f} \right)^{\frac{1}{c}}
\]

where subscripts \( i \) and \( f \) denote initial and final states respectively.
(b) Prove that for an irreversible expansion of a gas, the work done by the gas is given by \( w = -P\Delta V \) Joules where \( P \) is the external pressure and \( \Delta V \) is the increase in volume in \( m^3 \). (Use the simple example of a frictionless cylinder lying on its side)
(c) The enthalpy change for the following reaction is difficult to experimentally determine from calorimetric techniques:

\[ \text{C( graphite) + 2H}_2(\text{g}) \rightarrow \text{CH}_4(\text{g}). \quad \Delta H^0_{\text{rxn}} = ? \]

It can be determined, however, indirectly, by using the enthalpies of combustion of C( graphite), H₂( g) and CH₄( g) whose values are respectively (in kJ mol⁻¹): -393.51, -285.84 and -890.35. Using these data, determine \( \Delta H^0_{\text{rxn}} \).
For Bonus points only.  [10 points; 5 points each]

(a) Using the standard heat capacities at constant volume and constant pressure, prove that
\[ C_p - C_v = nR \] (or \( C_{p,m} - C_{v,m} = R \)).  \[ 5 \text{ points} \]

(b) The derivation in (a), above, applies to ideal gases. For real gases, the correct relationship is
\[ C_p - C_v = [P + \left( \frac{\delta U}{\delta V} \right)_T] \left( \frac{\delta V}{\delta T} \right)_P \]

Prove that this relationship gives you the simple relationship you derived in (a) when applied to ideal gases.  \[ 5 \text{ points} \]

[you can use the back of this page to complete your solution]