1. The energy emitted by a spherical blackbody is given by the Stefan-Boltzmann equation:

\[ E_{\text{out}} = 4\pi r^2 \times (5.67 \times 10^{-8}) \times T^4 = 4\pi \times (6.96 \times 10^8)^2 \times (5.67 \times 10^{-8}) \times (5800)^4 \]
\[ = 3.90 \times 10^{26} \text{ J s}^{-1} \]

This energy is emitted by the sun. By the time it reaches Earth, 1.50 \times 10^8 km away, it has been distributed over the surface of a sphere with surface area:

\[ \text{surface area} = 4\pi \times (1.50 \times 10^{11})^2 = 2.83 \times 10^{23} \text{ m}^2 \]

The energy flux per unit area is therefore:

\[ \text{energy flux} = \frac{E_{\text{out}}}{\text{surface area}} = 3.90 \times 10^{26} / 2.83 \times 10^{23} = 1381 \text{ J m}^{-2} \text{ s}^{-1} \]

2. From Q1, \(E_{\text{out}} = 3.90 \times 10^{26} \text{ J s}^{-1}\) from the sun. By the time it reaches Venus, it has been distributed over the surface of a sphere with surface area:

\[ \text{surface area} = 4\pi \times (1.09 \times 10^{11})^2 = 1.49 \times 10^{23} \text{ m}^2 \]

The energy flux per unit area is therefore:

\[ \text{energy flux} = \frac{E_{\text{out}}}{\text{surface area}} = \frac{3.90 \times 10^{26}}{1.49 \times 10^{23}} = 2612 \text{ J m}^{-2} \text{ s}^{-1} \]

With an albedo of 65\%, 35\% is not reflected. Hence,

\[ E_{\text{in}} = \pi r^2 \times 2612 \times 0.35 \text{ and } E_{\text{out}} = 4\pi r^2 \times (5.67 \times 10^{-8}) \times T^4 \]

As \(E_{\text{out}} = E_{\text{in}}\):

\[ T^4 = \frac{2612 \times 0.35}{4 \times 5.67 \times 10^{-8}} \text{ or } T = 252 \text{ K}. \]

3. (a) The wavelength of the maximum emission is given by Wien’s displacement law:

\[ T \times \lambda_{\text{max}} \sim (2.898 \times 10^6) \times T \text{ (K nm)} \]

\[ \lambda_{\text{max}} \sim \frac{2.898 \times 10^6}{(3400 + 273)} = 790 \text{ nm} \]

(b) As 1 cm = 10\(^7\) nm, the wavenumber is:

\[ \nu = \frac{1}{(790 \times 10^{-7})} = 13000 \text{ cm}^{-1} \]
4. The total pressure is the sum of the partial pressures due to each gas. The partial pressure of each gas is:

\[
p(N_2) = \frac{55.0}{100} \times 1.00 = 0.550 \text{ atm}
\]

\[
p(O_2) = \frac{25.0}{100} \times 1.00 = 0.250 \text{ atm}
\]

\[
p(CO_2) = \frac{20.0}{100} \times 1.00 = 0.200 \text{ atm}
\]

The partial pressures do indeed sum to give the total pressure:

\[
\text{total pressure} = \sum p(X) = 0.550 + 0.250 + 0.200 = 1.00 \text{ atm}
\]

5. As \( q = nC\Delta T \), if the same amount of heat is used \( \text{Cl}_2 \) will become hotter than \( \text{H}_2\text{O} \) as it has a lower molar capacity, \( C \).

For \( \text{Cl}_2, \Delta T = \frac{q}{nC} = \frac{1 \times 10^3}{1 \times 37.0} = 27.0 \text{ K} \). For \( \text{H}_2\text{O(l)}, \Delta T = \frac{q}{nC} = \frac{1 \times 10^3}{1 \times 75.3.0} = 13.3 \text{ K} \).

6. The neutralization reaction is a 1:1 reaction with chemical equation:

\[
\text{HCl(aq)} + \text{NaOH(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}
\]

After the reactants mix the solution has a volume of 200 mL. The density of water is 1.0 g mol\(^{-1}\), so the mass of water is 200 g. The temperature change, \( \Delta T = 31.1 - 24.6 = 6.7 \text{ K} \). The heat capacity of water is 4.184 J K\(^{-1}\) g\(^{-1}\). The heat change is therefore:

\[
q = c \times m \times \Delta T = 4.184 \times 200 \times 6.7 = 5600 \text{ J or 5.6 kJ} \quad \text{(heat released)}
\]

100 mL of 1.0 M HCl corresponds to:

\[
n = \text{concentration} \times \text{volume} = 1.0 \times \frac{100}{1000} = 0.10 \text{ mol}.
\]

The heat change for a mole would therefore be \( 10 \times 5600 \text{ J} \). The reaction gives out heat (as the temperature rises) so it is an exothermic reaction with a negative enthalpy change: \( \Delta H = -56 \text{ kJ mol}^{-1} \)

7. | Reaction                                                                 | \( \Delta H \) (kJ mol\(^{-1}\)) |
<table>
<thead>
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<tbody>
<tr>
<td>A ( 2 \text{B(s)} + \frac{3}{2} \text{O}_2(g) \rightarrow \text{B}_2\text{O}_3(s) )</td>
<td>-1273</td>
</tr>
<tr>
<td>B ( \text{B}_2\text{H}_6(g) + 3\text{O}_2(g) \rightarrow \text{B}_2\text{O}_3(s) + 3\text{H}_2\text{O(g)} )</td>
<td>-2035</td>
</tr>
<tr>
<td>C ( \text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{H}_2\text{O(l)} )</td>
<td>-286</td>
</tr>
<tr>
<td>D ( \text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{O(g)} )</td>
<td>+44</td>
</tr>
</tbody>
</table>
The enthalpy change for a reaction such as B can be written as the difference between the enthalpy of formation of reactants and products:

\[ \Delta H_{rxn}^o = \sum m \Delta H_f^o (\text{products}) - \sum n \Delta H_f^o (\text{reactants}) \]

For reaction B this becomes:

\[ \Delta H_{rxn}^o = \left[ \Delta H_f^o (B_2O_3(s)) + 3 \Delta H_f^o (H_2O(g)) \right] - \left[ \Delta H_f^o (B_2H_6(s)) + 3 \Delta H_f^o (O_2(g)) \right] \]

- Reaction A corresponds to the heat of formation of B₂O₃(s) so \( \Delta H_f^o (B_2O_3(s)) = -1273 \, \text{kJ mol}^{-1} \).
- Reaction C corresponds to formation of H₂O(l) and reaction D corresponds to the energy that must then be supplied to vapourize the liquid into H₂O(g):
  \( \Delta H_f^o (H_2O(g)) = -286 + 44 = -242 \, \text{kJ mol}^{-1} \).
- The enthalpy change for reaction B is \( \Delta H_{rxn}^o = -2035 \, \text{kJ mol}^{-1} \).
- As O₂ exists as a gas under standard conditions, its enthalpy of formation is zero.

Putting all this together gives:

\[ -2035 = \left[ -1273 + 3 \times -242 \right] - \left[ \Delta H_f^o (B_2H_6(s)) + 3 \times 0 \right] \]

Hence: \( \Delta H_f^o (B_2H_6(s)) = 36 \, \text{kJ mol}^{-1} \).

8. \( \text{C}_4\text{H}_{10}(g) + \frac{13}{2} \text{O}_2(g) \rightarrow 4\text{CO}_2(g) + 5\text{H}_2\text{O}(g) \)

(a) There are \( (1+\frac{13}{2}) = \frac{15}{2} \) moles of gas in the reactants and \( (4 + 5) = 9 \) moles of gas in the products. The reaction involves a net increase of \( \frac{3}{2} \) moles. The ideal gas equation gives the volume as \( V = \frac{nRT}{P} \). The change in volume is therefore:

\[ \Delta V = \frac{\Delta nRT}{P} = \frac{3}{2} \frac{RT}{P} \]

At \( P = 1 \, \text{atm} \) and \( T = 350 \, \text{L} \), the volume change is:

\[ \Delta V = \frac{3}{2} \times \frac{0.08206 \times 350}{1} = 43.1 \, \text{L} \]

The work done when this expansion occurs is given by:

\[ w' = PA\Delta V = (1 \times 101325) \times (43.1 \times 10^{-3}) = 4365 \, \text{J} \]

where the pressure and volume have been converted to the SI unit (Pa and m³ respectively.)
Alternatively,

\[ w' = P \Delta V = P \times \frac{\Delta nRT}{P} = \Delta nRT = \frac{3}{2} \times 8.314 \times 350 = 4365 \text{ J}. \]

(b) As \( H = E + PV \), at constant \( P \):

\[ \Delta H = \Delta E + P \Delta V = \Delta E + \Delta nRT \]

or

\[ \Delta H - \Delta E = \Delta nRT \]