Marks 3

- Ammonium perchlorate mixed with powdered aluminium powers the space shuttle booster rockets:

$$2NH_4ClO_4(s) + 2Al(s) \rightarrow Al_2O_3(s) + 2HCl(g) + 2NO(g) + 3H_2O(g)$$

Given the following thermochemical data, how much heat would be released per gram of Al(s)?

ΔH_f^o ($H_2O(l)$) = –285.1 kJ mol^{-1} ΔH_f^o ($Al_2O_3(s)$) = –1669.8 kJ mol^{-1}

ΔH_f^o ($NO(g)$) = 90.4 kJ mol^{-1} ΔH_f^o ($NH_4ClO_4(s)$) = –290.6 kJ mol^{-1}

ΔH_f^o ($HCl(g)$) = –92.3 kJ mol^{-1} ΔH_{vap}^o (H_2O) = 44.1 kJ mol^{-1}

Using $\Delta_{rxn}H^0 = \sum m\Delta_f H^0(\text{products}) - \sum n\Delta_f H^0(\text{reactants})$:

$$\Delta_{rxn}H^0 = \sum \Delta_f H°(Al_2O_3(s)) + 2\Delta_f H°(HCl(g)) + 2\Delta_f H°NO(g)) + 3\Delta_f H°(H_2O(g)) - \sum 2\Delta_f H°(NH_4ClO_4(s)) + 2\Delta_f H°(Al(s))$$
$$= [(-1669.8) + 2(-92.3) + 2(90.4) + 3(-285.1 + 44.1)] - [2(-290.6) + 2(0)]$$
$$= -1815.4 \text{ kJ mol}^{-1}$$

In this calculation, $\Delta_f H°(Al(s)) = 0$ for an element in its standard state and $\Delta_f H°(H_2O(g)) = \Delta_f H°(H_2O(l)) + \Delta_{vap} H°(H_2O)$ have been used.

As written, this enthalpy change is for the reaction of two moles of Al(s). Therefore, per mole of Al(s), $\Delta H° = ½ \times -1815.4$ kJ mol^{-1} =907.7 kJ mol^{-1}.

As the atomic mass of aluminium is 26.98 g mol^{-1}, the heat released per gram of Al is:

$$q = \frac{-907.7 \text{ kJ mol}^{-1}}{26.98 \text{ g mol}^{-1}} = 33.64 \text{ kJ g}^{-1}$$

Answer: **33.64 kJ g^{-1}**

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