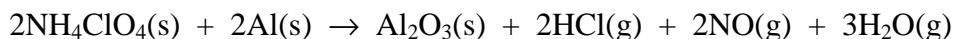


- Ammonium perchlorate mixed with powdered aluminium powers the space shuttle booster rockets:



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

$$\Delta H_f^\circ (\text{H}_2\text{O}(\text{l})) = -285.1 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\circ (\text{Al}_2\text{O}_3(\text{s})) = -1669.8 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\circ (\text{NO}(\text{g})) = 90.4 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\circ (\text{NH}_4\text{ClO}_4(\text{s})) = -290.6 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\circ (\text{HCl}(\text{g})) = -92.3 \text{ kJ mol}^{-1}$$

$$\Delta H_{\text{vap}}^\circ (\text{H}_2\text{O}) = 44.1 \text{ kJ mol}^{-1}$$

**Marks**  
**3**

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

$$\begin{aligned} \Delta_{\text{rxn}} H^\circ &= \sum \Delta_f H^\circ (\text{Al}_2\text{O}_3(\text{s})) + 2\Delta_f H^\circ (\text{HCl}(\text{g})) + 2\Delta_f H^\circ (\text{NO}(\text{g})) + 3\Delta_f H^\circ (\text{H}_2\text{O}(\text{g})) \\ &\quad - \sum 2\Delta_f H^\circ (\text{NH}_4\text{ClO}_4(\text{s})) + 2\Delta_f H^\circ (\text{Al}(\text{s})) \\ &= [(-1669.8) + 2(-92.3) + 2(90.4) + 3(-285.1 + 44.1)] - [2(-290.6) + 2(0)] \\ &= -1815.4 \text{ kJ mol}^{-1} \end{aligned}$$

In this calculation,  $\Delta_f H^\circ (\text{Al}(\text{s})) = 0$  for an element in its standard state and  $\Delta_f H^\circ (\text{H}_2\text{O}(\text{g})) = \Delta_f H^\circ (\text{H}_2\text{O}(\text{l})) + \Delta_{\text{vap}} H^\circ (\text{H}_2\text{O})$  have been used.

As written, this enthalpy change is for the reaction of two moles of Al(s). Therefore, per mole of Al(s),  $\Delta H^\circ = \frac{1}{2} \times -1815.4 \text{ kJ mol}^{-1} = -907.7 \text{ kJ mol}^{-1}$ .

As the atomic mass of aluminium is  $26.98 \text{ g mol}^{-1}$ , 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<sup>-1</sup>**

**THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.**