

Solutions

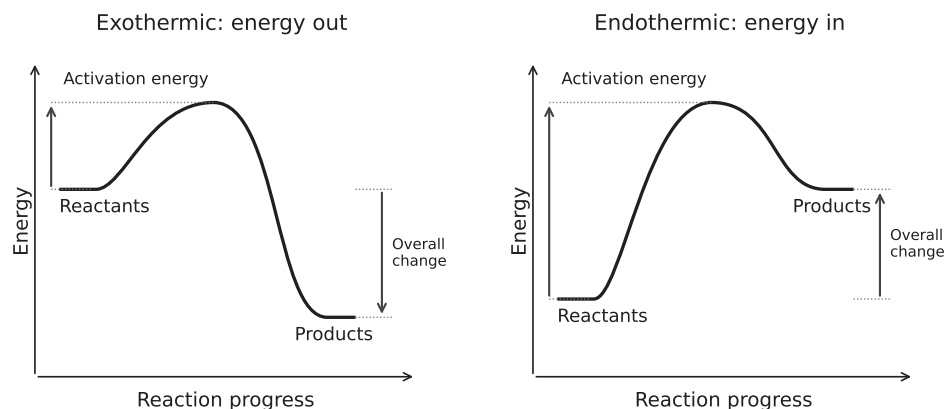
2.1 Endothermic – the surroundings cool.

2.2 Activation energy.

2.3 Hand warmer / self-heating can.

2.4 Combustion / neutralisation / a named oxidation (1); thermal decomposition / citric acid with sodium hydrogencarbonate (1). No (1): a physical process can change temperature; chemical-reaction evidence needs new substance formation (1).

3.1 Products drawn above reactants; a curved line from reactants over a hump; activation energy arrow from reactant level to the peak; overall energy change arrow from reactant level up to product level.



3.2 Overall change = $1000 - 850 = +150$ kJ/mol; positive – energy taken in; endothermic reaction.

3.3 The hand warmer is exothermic, transferring energy to the surroundings/hands (1); it stops before the 45-minute activity ends because a reactant runs out (1). The cold pack is endothermic, taking energy from the surroundings/injury (1); 15 minutes is shorter than the activity and another pack would be needed for continued cooling (1). Both are single-use, increasing material use/waste if replaced; assess whether continuous warming/cooling is actually needed rather than assuming it (1). The supplied data do not establish whether a skin temperature is safe.

3.4 Break four C–H bonds and two O=O bonds (1); form two C=O bonds and four O–H bonds (1). Broken = $4 \times 413 + 2 \times 498 = 2648$ kJ/mol (1); formed = $2 \times 805 + 4 \times 464 = 3466$ kJ/mol (1). Overall = $2648 - 3466 = -818$ kJ/mol (1), exothermic because formation releases more than breaking requires (1). The result refers to the quantities in the balanced equation.

3.5 Use a supported insulated cup, thermometer/probe and measured acid/alkali portions (1). Record initial temperature, add measured alkali portions, stir and record highest temperature against total volume (1). Keep acid volume, concentrations and starting temperatures comparable; cup/procedure also controlled (1). Repeat the whole investigation with fresh solutions and calculate means at corresponding volumes (1).

Eye protection and teacher-approved solutions/handling; alkali is an eye hazard (1). Lid/insulation reduces heat exchange with the room, improving temperature evidence but not eliminating losses (1).

3.6 Mean peak = $(30.0 + 29.6 + 29.8)/3 = 29.8$ °C (1); rise = $29.8 - 20.0 = 9.8$ °C (1). Plot temperature against total alkali volume with appropriate scales/labels (1); use appropriate best-fit lines through rising/falling regions to estimate their intersection (1). Discrete volume steps, reading uncertainty and heat exchange mean the highest measured point need not be the true maximum/endpoint (1).

3.7 Activation energy = $95 - 30 = 65$ relative units (1). Overall = $55 - 30 = +25$ relative units (1), endothermic (1). A catalyst lowers the peak/activation energy (1), leaving reactant/product levels and overall change unchanged (1). The horizontal axis is reaction progress, not time (1).