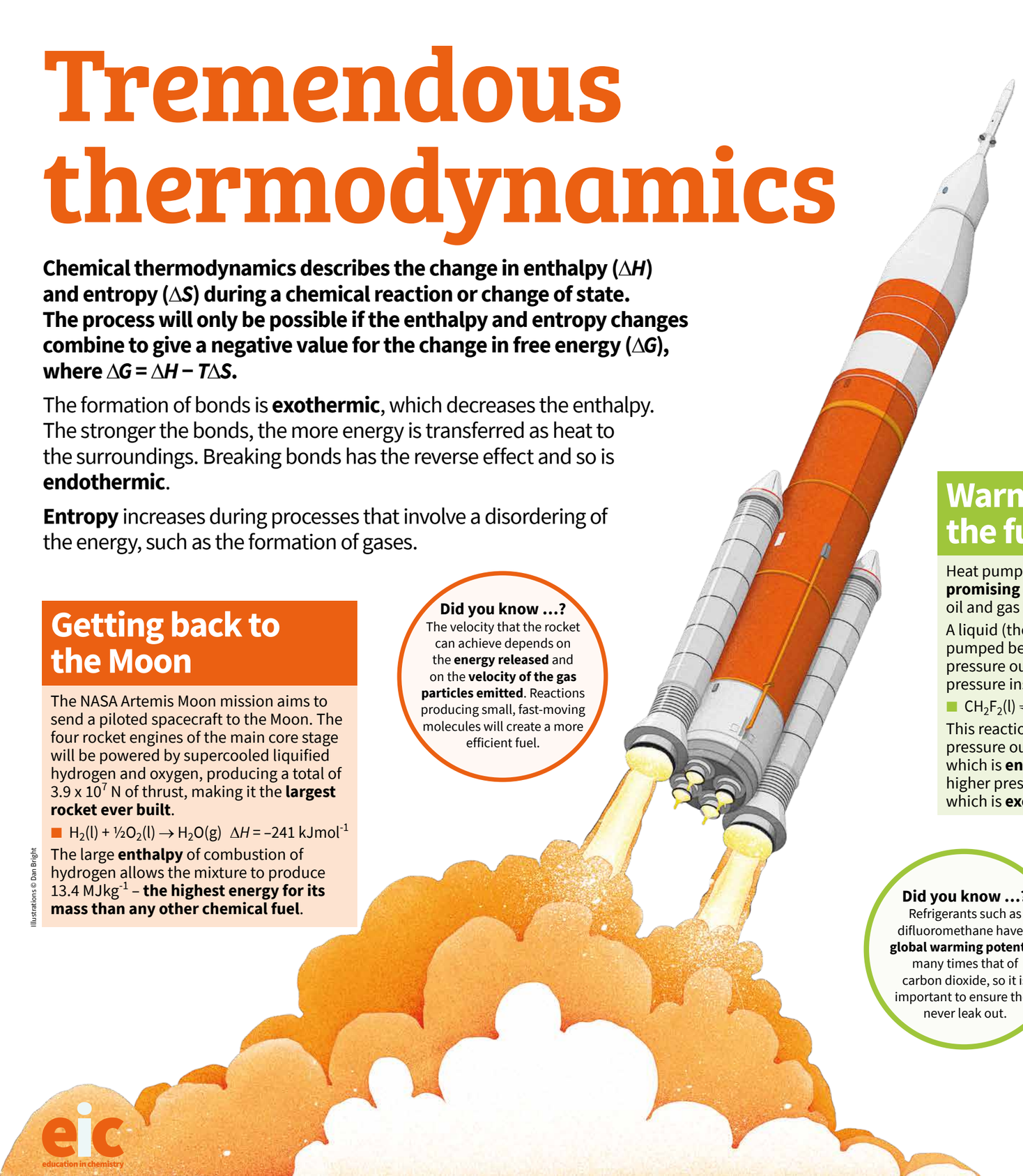
Tremendous thermodynamics

Chemical thermodynamics describes the change in enthalpy (ΔH) and entropy (ΔS) during a chemical reaction or change of state. The process will only be possible if the enthalpy and entropy changes combine to give a negative value for the change in free energy (ΔG), where $\Delta G = \Delta H - T\Delta S$.

The formation of bonds is **exothermic**, which decreases the enthalpy. The stronger the bonds, the more energy is transferred as heat to the surroundings. Breaking bonds has the reverse effect and so is **endothermic**.

Entropy increases during processes that involve a disordering of the energy, such as the formation of gases.



Getting back to the Moon

The NASA Artemis Moon mission aims to send a piloted spacecraft to the Moon. The four rocket engines of the main core stage will be powered by supercooled liquified hydrogen and oxygen, producing a total of 3.9×10^7 N of thrust, making it the **largest rocket ever built**.

■ $H_2(l) + \frac{1}{2}O_2(l) \rightarrow H_2O(g)$ $\Delta H = -241$ kJmol^{-1}

The large **enthalpy** of combustion of hydrogen allows the mixture to produce 13.4 MJkg^{-1} – **the highest energy for its mass than any other chemical fuel**.

Did you know …?
The velocity that the rocket can achieve depends on the **energy released** and on the **velocity of the gas particles emitted**. Reactions producing small, fast-moving molecules will create a more efficient fuel.

Did you know …?
Bicarbonate of soda **relies on the presence of naturally occurring acids in the baking mixture**. In recipes where these are not present in sufficient quantities, then baking powder, which also includes an acid, is used instead.

Perfect biscuits and cakes

Baking often requires a **raising agent** to create bubbles in the mixture. The most common raising agent is sodium hydrogen carbonate (sodium bicarbonate), which produces carbon dioxide, giving a light, airy texture.

■ $NaHCO_3(s) + H^+(aq) \rightarrow Na^+(aq) + H_2O(l) + CO_2(g)$.
$\Delta H^\ominus = +28$ kJmol^{-1} $\Delta S^\ominus = +241$ JK^{-1}mol^{-1}

This reaction is **endothermic**, but it occurs because of the **large increase in entropy that results from the formation of a gas.**

Warm homes for the future

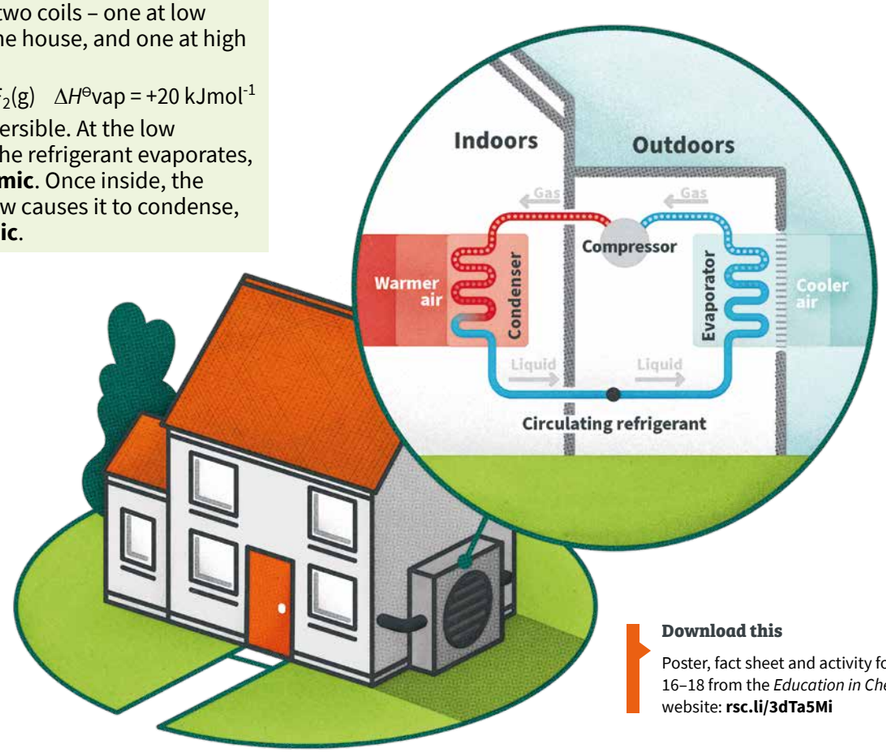
Heat pumps are currently one of the **most promising carbon-neutral alternatives** to oil and gas boilers.

A liquid (the refrigerant) is continually pumped between two coils – one at low pressure outside the house, and one at high pressure inside.

■ $CH_2F_2(l) \rightleftharpoons CH_2F_2(g)$ $\Delta H^\ominus vap = +20$ kJmol^{-1}

This reaction is reversible. At the low pressure outside, the refrigerant evaporates, which is **endothermic**. Once inside, the higher pressure now causes it to condense, which is **exothermic**.

Did you know …?
Refrigerants such as difluoromethane have a **global warming potential** many times that of carbon dioxide, so it is important to ensure they never leak out.



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