The Arrhenius equation describes the relationship between the rate constant and temperature.

$$k = A\,\mathrm{e}^{-E_a/RT}$$

The uncatalysed reaction between xenon and fluorine to form XeF_2 at a temperature T has a rate constant k, with collision frequency factor A and activation energy E_a. R is the universal gas constant.

When a nickel difluoride catalyst is added to the reaction mixture, the rate constant changes to k_{cat}, with a different collision frequency A_{cat} and activation energy E_{cat}. It is found that the catalysed reaction is 13 times faster at 120 °C and 23 times faster at 100 °C.

The change in activation energy $\Delta E = E_a - E_{cat}$.

(f) Write an expression for the ratio k_{cat}/k in terms of T, A, A_{cat}, ΔE and any constants.

(g) Calculate the change in activation energy, ΔE, in kJ mol^{-1}, assuming that the collision frequency factors do not depend on temperature.

The rate-determining step in the uncatalysed formation of xenon difluoride is the reaction of atomic fluorine with xenon, $F_{(g)} + Xe_{(g)} \rightarrow XeF_{(g)}$. A more refined kinetic theory expresses the rate constant of this reaction as:

$$k = \beta\left(\frac{T}{\mu}\right)^{\frac{1}{2}} \mathrm{e}^{-E_a/RT}$$

where β is a constant and μ is a reduced mass, neither of which depend on temperature. The rate constant has the following values at different temperatures:

T / °C	50	70	100	130	170
k / dm^3 mol^{-1} s^{-1}	1.55×10^{-10}	1.19×10^{-9}	1.70×10^{-8}	1.63×10^{-7}	2.07×10^{-6}

(h) Determine the activation energy of this reaction using the data tabulated above.

When xenon was discovered in 1898 it was assigned a relative atomic mass of 128, which is mistakenly reported as 28 in the picture at the start of the question. The relative atomic mass has since been refined to its current value of 131.29.

The rate constant depends on the reduced mass, μ, where:

$$\frac{1}{\mu} = \frac{1}{M_{\mathrm{Xe}}} + \frac{1}{M_{\mathrm{F}}}$$

M_{Xe} and M_{F} are the atomic masses of xenon and fluorine in g mol^{-1} as given in the periodic table at the end of the paper.

(i) Determine the rate constant for the reaction F + Xe → XeF at 100 °C if the atomic mass of xenon was 28 g mol^{-1}. Assume all other parameters remained unchanged.

Acknowledgements & References

Q1 The image is © Dr Ben Pilgrim
Phosphine gas in the cloud decks of Venus *Nature Astronomy*, **2020**,
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Q2 The image is © Science Photo Library
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Q3 The image is © Getty Images
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Q4 The image is © Shutterstock

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https://www.bbc.co.uk/news/world-us-canada-52399464

Q6 The image is © Dr George Trenins. The original public domain image was a caricature of Ramsay by Leslie Ward, in *Vanity Fair* in 1908. Ramsay was pointing to krypton in the original image that contained the wrong relative atomic mass. The image was edited for this paper so that Ramsay was pointing to xenon, but we did not correct the relative atomic mass.
Data is adapted from **On the xenon-fluorine reactions** *Journal of Inorganic and Nuclear Chemistry*, **1976**, *28*, 173-178.
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