Exam skills 4

This exam-style question uses knowledge and skills you have already revised. Look at pages 39, 42, 46 and 53 for a reminder about enthalpy profile diagrams, enthalpy of neutralisation, using bond enthalpies and the equilibrium constant.

Worked example

Hydrogen reacts with fluorine to form hydrogen fluoride.

$H_2 + F_2 \rightleftharpoons 2HF$

(a) (i) Write an expression for the equilibrium constant, K_c. **(1 mark)**

$K_c = \dfrac{[HF]^2}{[H_2][F_2]}$

Remember to include the numbers in the equation as powers in the equilibrium expression.

(ii) At equilibrium, there are 0.25 mol of hydrogen, 0.30 mol of fluorine and 2.0 mol of hydrogen fluoride in a container of volume 10 dm^3. Calculate K_c, with units if any. **(2 marks)**

$$K_c = \frac{\left(\frac{2.0}{10}\right)^2}{\left(\frac{0.25}{10}\right)\left(\frac{0.30}{10}\right)} = \frac{4}{0.075} = 53 \text{ (no units)}$$

Maths skills Square brackets mean concentration in mol dm^{-3}. When substituting into K_c, the moles are divided by the volume (10 dm^3) to get concentration.
In this case, there are the same number of moles on each side of the equation, so the volumes cancel. It is still useful to include the volume so that it is not forgotten when it does not cancel. This also means that Kc has no units in this case.

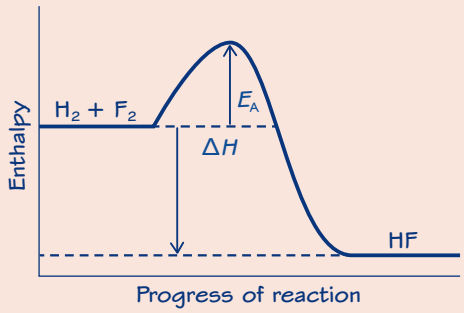
(b) (i) Calculate the standard enthalpy change of this reaction, given the average bond enthalpies below. **(3 marks)**

Bond	Average bond enthalpy / kJ mol^{-1}
H–H	432
F–F	159
H–F	569

Enthalpy of bonds broken = 432 + 159 = 591 kJ mol^{-1}
Enthalpy of bonds formed = 2 × 569 = 1138 kJ mol^{-1}
$\Delta_r H$ = 591 − 1138
= −547 kJ mol^{-1}

Maths skills Carefully show your working so that if you make a slip the examiner can follow and award part-marks. Don't forget units.

(ii) Using your answer to (b)(i), sketch an energy profile diagram for the reaction, labelling E_A and ΔH. **(3 marks)**



The shape of this diagram is important – see page 39 for the different enthalpy profile diagrams for exothermic and endothermic reactions. You can see that this diagram is for an exothermic reaction, because the answer to (b) (ii) is negative.

(c) The standard enthalpy of neutralisation of hydrofluoric acid, a weak acid, with sodium hydroxide solution is −59 kJ mol^{-1}. Suggest why this is different from the standard enthalpy of neutralisation of hydrochloric acid with sodium hydroxide solution. **(3 marks)**

'Suggest' means that you may not have been taught this idea directly, but you should apply your knowledge to an unknown situation. In this case, the information that HF is a weak acid is the key to forming an answer.

Strong acids and alkalis are fully ionised, so neutralisation is $H^+ + OH^- \rightarrow H_2O$. As HF is a weak acid, only a small proportion of the molecules are ionised. When undissociated HF molecules are changed into ions in solution, there is an enthalpy change which alters the standard enthalpy of neutralisation.