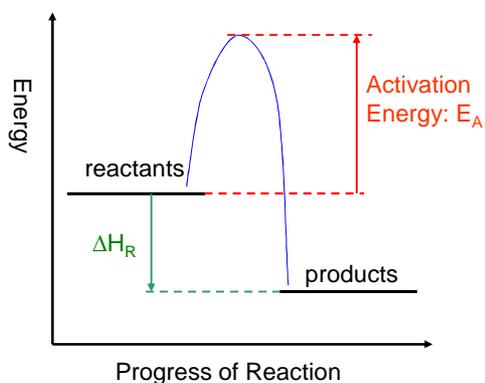


## Rates and Temperature

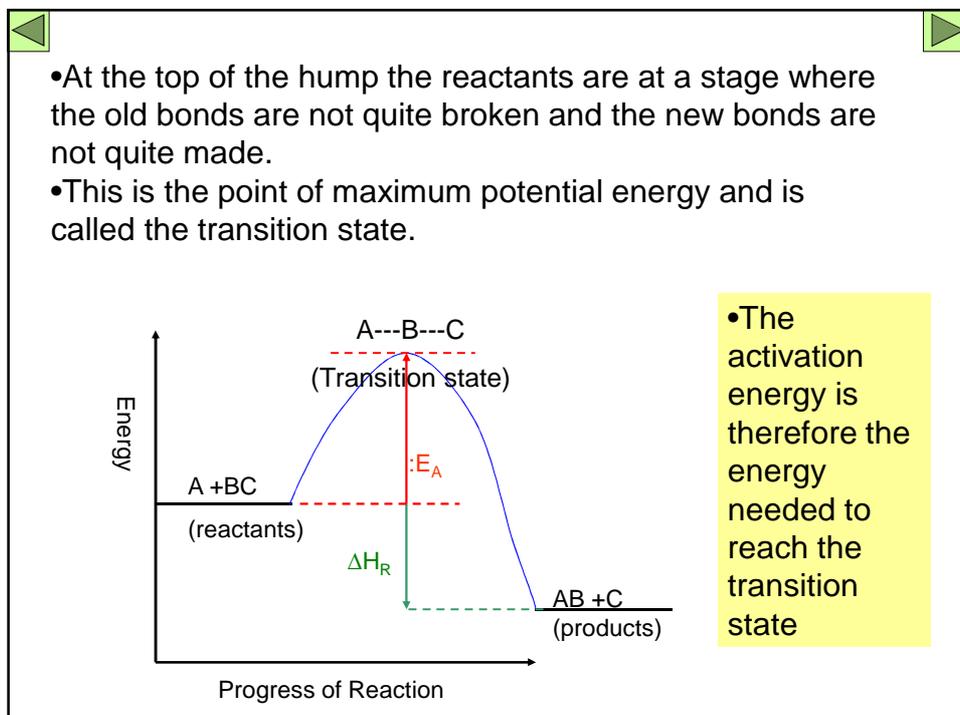
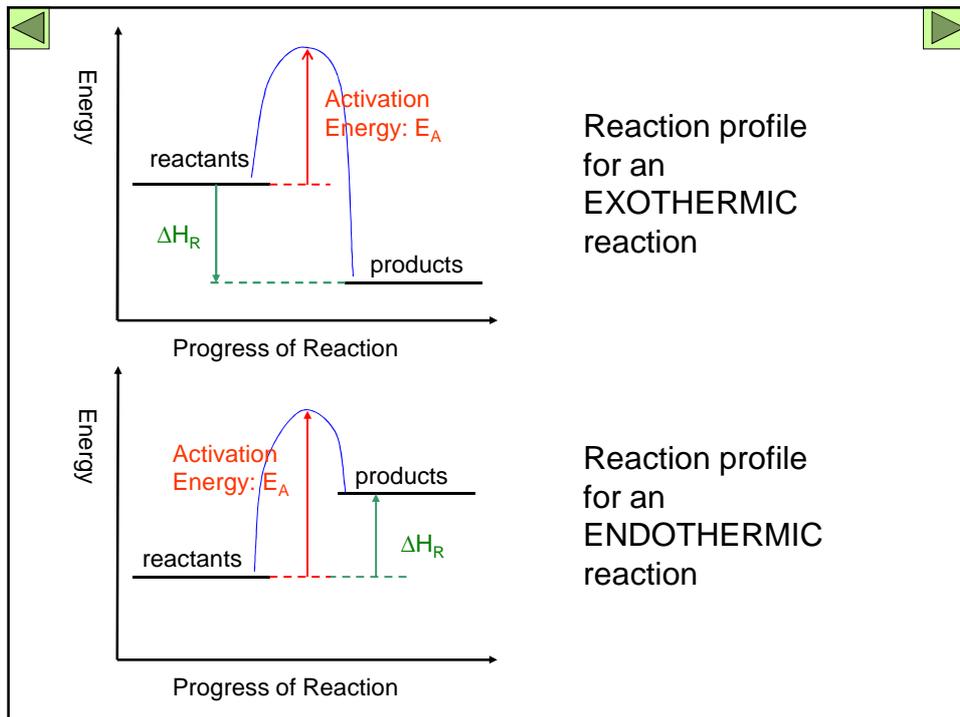
N Goalby  
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## Activation Energy

Molecules will only react if they collide with enough energy to break the relevant bonds in one or either of the reactant molecules. This is the minimum energy required and is called the activation energy.

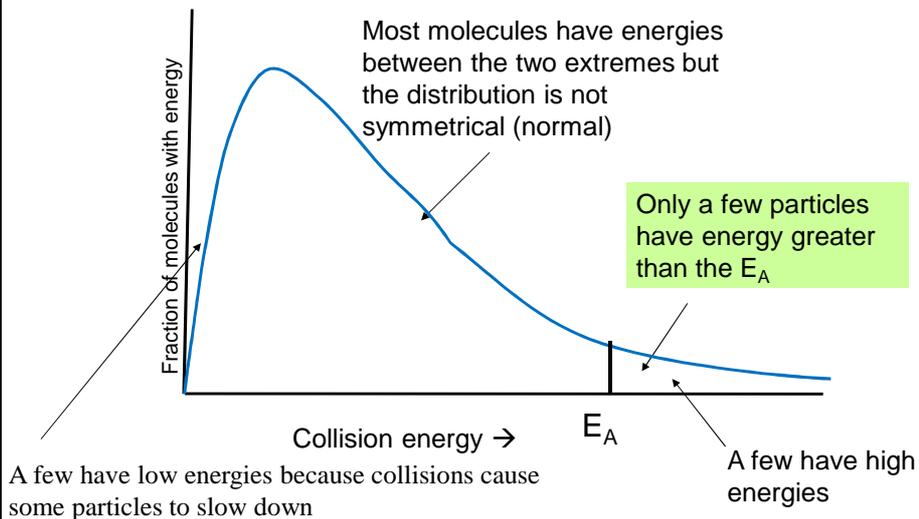


The activation energy is usually equal to the energy required to break the relevant bonds in the reactants.

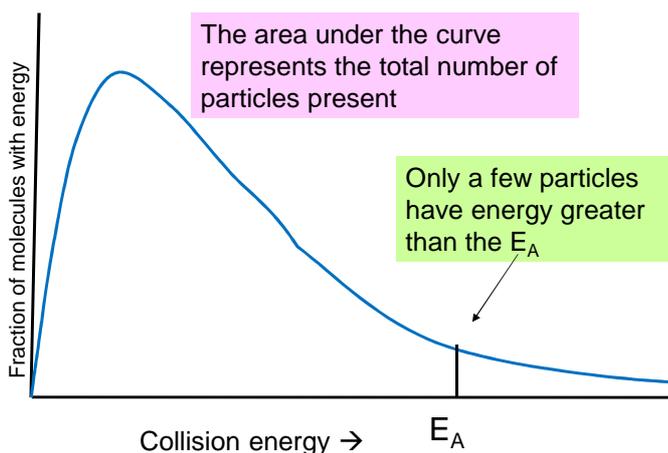


## Maxwell Boltzmann Distribution

The Maxwell-Boltzmann energy distribution shows that any one temperature the molecules in a gas have a range of different energies.

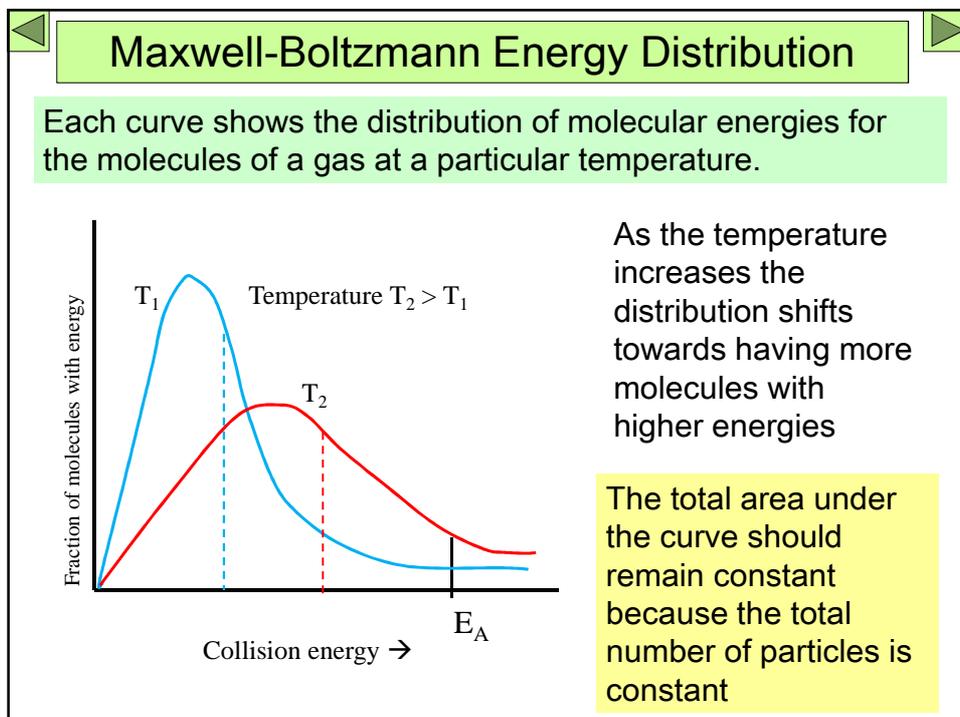
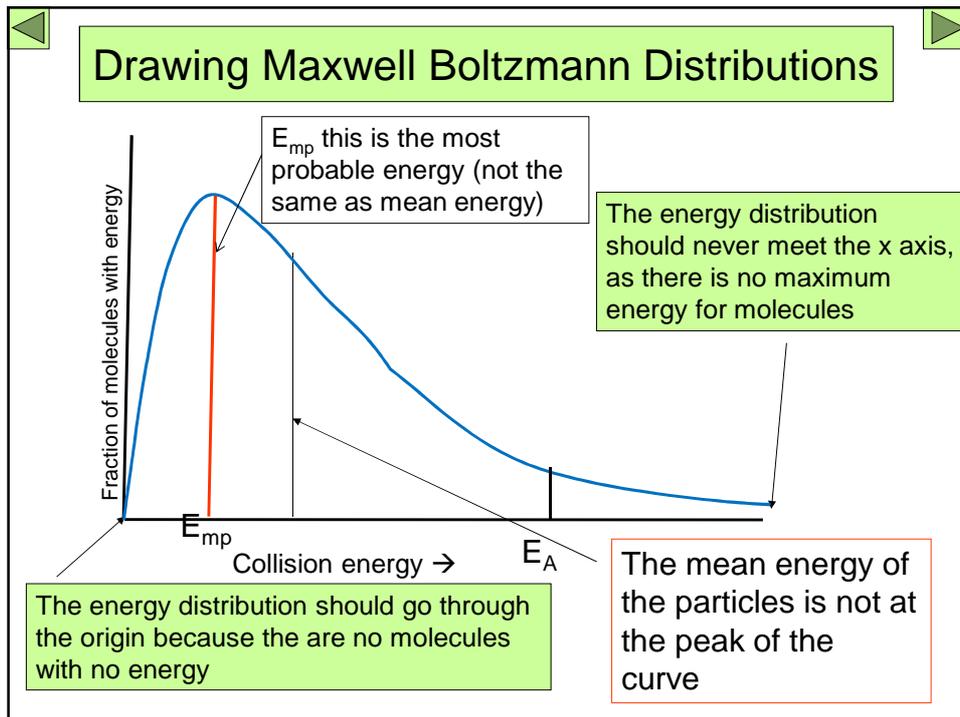


## Maxwell Boltzmann Distribution

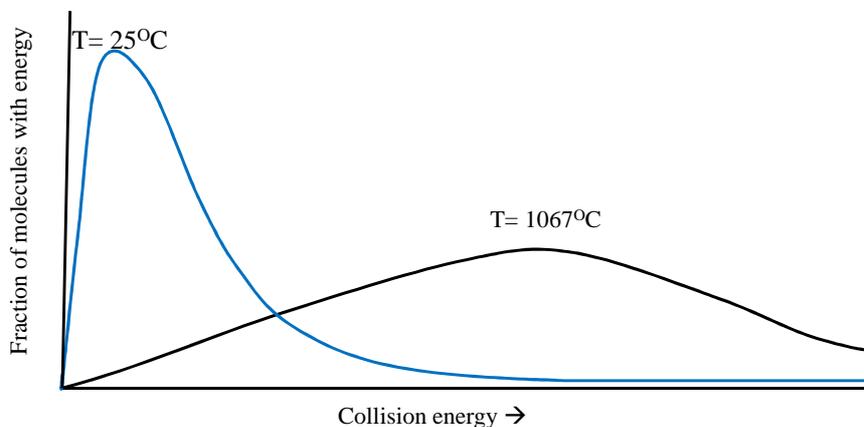


How can a reaction go to completion if few particles have energy greater than  $E_a$ ?

Particles can gain energy through collisions



### Energy Distributions for large temperature differences



At higher temperatures the molecules have a wider range of energies than at lower temperatures.

### Effect of Temperature on reaction rate

The rate constant,  $k$ , in rate equations is dependent on temperature. If the temperature is constant the rate constant stays the same.

$$r = k[A]^m[B]^n$$

The rate constant  $k$  in the rate equation **increases with higher temperatures.**

key

## Arrhenius

The relationship between rate constant and temperature is governed by the Arrhenius equation

$$k = A e^{-(E_a/RT)}$$

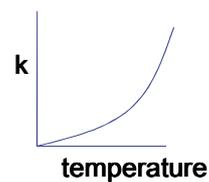
- k : rate constant
- A : a constant
- e : a number on calculator
- E<sub>a</sub> : activation energy
- R : gas constant 8.31 J K<sup>-1</sup> mol<sup>-1</sup>
- T : temperature in Kelvin (K)

extra

Remember k is the same for all experiments done at the same temperature.

Increasing the temperature increases the value of the rate constant k

Increasing temperature increases the rate constant k. The relationship is given by the Arrhenius equation  $k = Ae^{-E_a/RT}$  where A is a constant R is gas constant and E<sub>a</sub> is activation energy.



You do not need to learn or use the Arrhenius equation but be aware that the relationship between k and Temperature is not directly proportional but is shown on the graph to the right

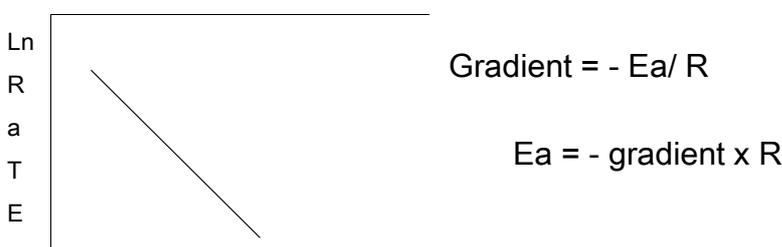
Using the arrhenius equation to calculate a value of activation energy

The arrhenius equation can be rearranged

$$\ln k = \text{constant} - E_a/(RT)$$

k is proportional to the rate of reaction so  $\ln k$  can be replaced by  $\ln(\text{rate})$

From plotting a graph of  $\ln(\text{rate})$  or  $\ln k$  against  $1/T$  the activation energy can be calculated



Ln  
R  
a  
t  
e

1/T

Gradient = -  $E_a/R$

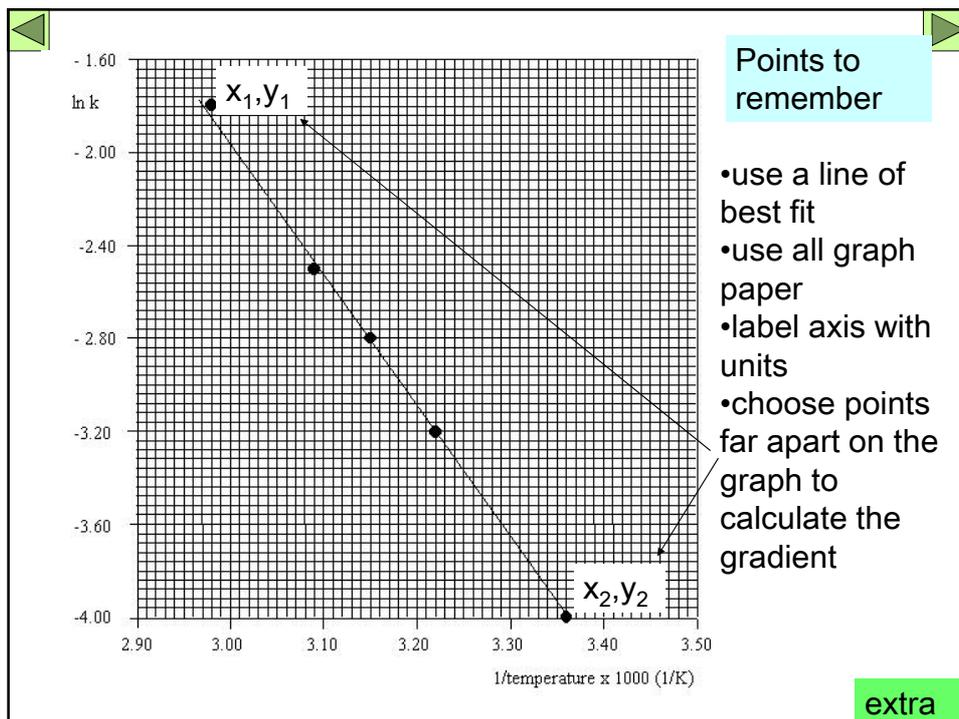
$E_a = - \text{gradient} \times R$

extra

Some typical results for an experiment to determine activation energy

Temperature /°C	Temperature T /K	1/T /K <sup>-1</sup>	Time t /s	1/t (ie rate) /s <sup>-1</sup>	ln(rate)
24.3	297.5	0.00336	53	0.019	-4.0
37.6	310.8	0.00322	24	0.042	-3.2
44.2	317.4	0.00315	16	0.063	-2.8
50.9	324.1	0.00309	12	0.083	-2.5
62.6	335.8	0.00298	6	0.17	-1.8

extra



### Calculating gradient

$$\text{gradient} = \frac{y_2 - y_1}{x_2 - x_1}$$

The gradient should always be -ve

if 1/T is given as  $3 \times 10^{-3}$  don't forget to include powers in the gradient

Use this relationship to work out  $E_a$  gradient =  $-E_a/R$

$$E_a = -\text{gradient} \times R \quad (8.31)$$

The unit of  $E_a$  using this equation will be  $\text{J mol}^{-1}$ . Convert into  $\text{kJ mol}^{-1}$  by dividing 1000

Never give answer to more than 3 sig fig (generally will be 2)

Give answer a + sign

**extra**