6.1 Collision theory and rates of reaction	
Nature of science: The principle of Occam's razor is used as a guide to developing a theory—although we cannot directly see reactions taking place at the molecular level, we can theorize based on the current atomic models. Collision theory is a good example of this principle. (2.7)	
Understandings: • Species react as a result of collisions of sufficient energy and proper orientation. • The rate of reaction is expressed as the change in concentration of a particular reactant/product per unit time. • Concentration changes in a reaction can be followed indirectly by monitoring changes in mass, volume and colour. • Activation energy (E_a) is the minimum energy that colliding molecules need in order to have successful collisions leading to a reaction. • By decreasing E_a, a catalyst increases the rate of a chemical reaction, without itself being permanently chemically changed. **Applications and skills:** • Description of the kinetic theory in terms of the movement of particles whose average kinetic energy is proportional to temperature in Kelvin. • Analysis of graphical and numerical data from rate experiments.	**International-mindedness:** • Depletion of stratospheric ozone has been caused largely by the catalytic action of CFCs and is a particular concern in the polar regions. These chemicals are released from a variety of regions and sources, so international action and cooperation have been needed to ameliorate the ozone depletion problem. **Theory of knowledge:** • The Kelvin scale of temperature gives a natural measure of the kinetic energy of gas whereas the artificial Celsius scale is based on the properties of water. Are physical properties such as temperature invented or discovered? **Utilization:** Syllabus and cross-curricular links: Topic 5.3—what might be meant by thermodynamically stable vs kinetically stable? Topic 13.1—fireworks and ions Option A.3—everyday uses of catalysts Option B.2—enzymes Biology topic 8.1—metabolism
• Explanation of the effects of temperature, pressure/concentration and particle size on rate of reaction. • Construction of Maxwell–Boltzmann energy distribution curves to account for the probability of successful collisions and factors affecting these, including the effect of a catalyst. • Investigation of rates of reaction experimentally and evaluation of the results. • Sketching and explanation of energy profiles with and without catalysts. **Guidance:** • Calculation of reaction rates from tangents of graphs of concentration, volume or mass vs time should be covered. • Students should be familiar with the interpretation of graphs of changes in concentration, volume or mass against time.	**Aims:** • **Aims 1** and **8**: What are some of the controversies over rate of climate change? Why do these exist? • **Aim 6**: Investigate the rate of a reaction with and without a catalyst. • **Aim 6**: Experiments could include investigating rates by changing concentration of a reactant or temperature. • **Aim 7**: Use simulations to show how molecular collisions are affected by change of macroscopic properties such as temperature, pressure and concentration. • **Aim 8**: The role that catalysts play in the field of green chemistry.

UNIT 6.1 – COLLISION THEORY AND RATES OF REACTION

Essential idea: The greater the probability that molecules will collide with sufficient energy and proper orientation, the higher the rate of reaction.

COLLISION THEORY

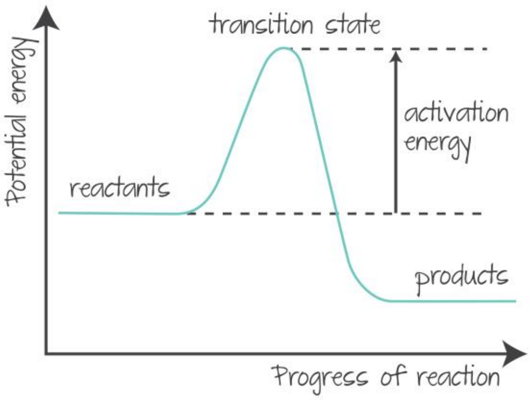
Simple collision theory states that before a chemical reaction can occur, the following requirement must be met:

- The reactants must physically collide and come into direct contact with each other.
- The colliding particles much have sufficient energy. This is known as activation energy E_a.
- The molecules must collide in the correct relative positions. “Collision geometry”

If these conditions aren’t met particles may simply bounce apart without changing.

ACTIVATION ENERGY

Activation Energy (E_a): The fixed amount of kinetic energy needed to overcome an endothermic ‘energy barrier’.

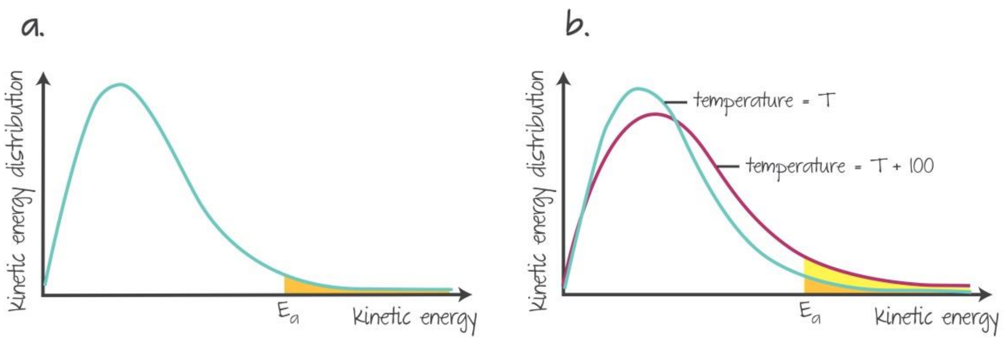


Fast reactions: Low E_a

Slow reactions: High E_a

DISTRIBUTION OF ENERGY

Maxwell–Boltzmann distribution curve: A graph that represents how many particles in a substance have enough E_a.



- As temperature increases, the peak of the curve moves to the right, so the most likely value of kinetic energy for the molecules increases.
- The area under the curve to the right of the activation energy, Ea, increases. This means that at higher temperatures a greater percentage of molecules have energies equal to or in excess of the activation energy, Ea.

RATES OF REACTION

The change of concentration of reactants or products over time.

AVERAGE RATE OF REATION

$$Rate = -\frac{concentration\ of\ R\ at\ time\ t_2 - concentration\ or\ R\ at\ time\ t_1}{t_2 - t_1}$$

$$= -\frac{\Delta[R]}{\Delta t}$$

The negative sign is needed to ensure a positive value is produced.

INSTANTANEOUS RATE OF REATION

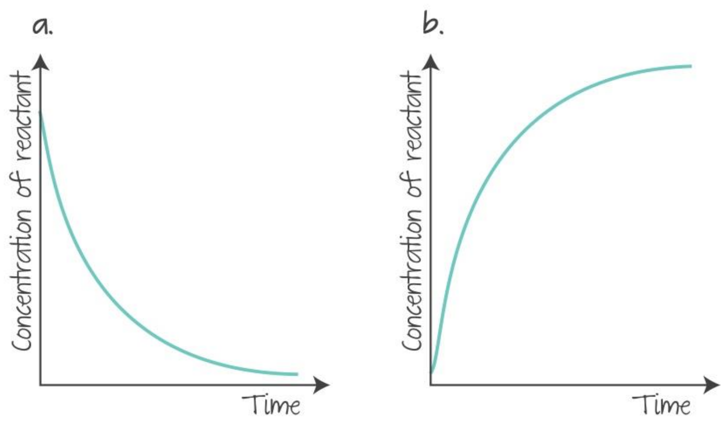
The tangent of the curve

$$\lim_{\Delta t \to 0} \frac{\Delta[R]}{\Delta t} = \frac{d[R]}{dt}$$

EXPERIMENTAL RATE OF REATION

Experimentally we can find the rate of reaction by measuring:

- Change in pH
- Change in conductivity
- Change in mass or volume
- Change in colour



CATALYSTS

Catalysts increase the rate of reactions by providing an **alternate pathway** for the reaction that has a lower E_a than before.