~~bonding~~ BONDING

WHY DO ATOMS BOND?
- to reach the most stable energy state
  - ↳ gain stable electron configuration
    - ↳ noble gas (8 in outer shell)
  - ↳ can either share electrons or take/lose electrons (transfer)
    - ↳ often form an ion (charged particle)

3 KINDS
ionic
↳ metal + non-metal

metallic
↳ metal + metal

covalent
↳ non-metal + non-metal

~~ionic compounds + bonding~~
CATIONS + ANIONS
- metals have 1-4 valence electrons + relatively low electronegativity & 1st ionisation energy
- valence electrons are removed easily
- will generally form a cation

- non-metals have 4-8 valence electrons + higher electronegativity and 1st ionisation energy
- will gain extra e^- needed to gain noble gas configuration
- will form an anion

HOW THEY FORM
- non-metal attracts e^- more
  - ↳ takes from the metal
  - ↳ ∴ forms cations & anions
  - ↳ cations & anions attract and form the ionic bond
  - ↳ strong electrostatic attraction
  - ↳ 3-dimensional - each cation attracts an anion in all directions
  - ↳ ionic compounds = crystal lattice structure

POLYATOMIC IONS
- ions formed from a single atom = monatomic
- ions formed from 2 or more atoms = polyatomic
- in some cases, the anion or cation may be a polyatomic ion
  - ↳ ions made of more than one atom
    - e.g. hydroxide (OH^-) or ammonium (NH_4^+)

STRUCTURE
- in solid state, ionic compound consists of the ions held in an orderly 3-D lattice
- the electrostatic attraction between the cations & anions occurs in all directions

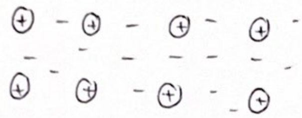
PROPERTIES OF IONIC COMPOUNDS
ionic compounds are hard + brittle
- held together firmly ∴ hard
- disruption causes like charges to come closer together + repel ∴ shatters ∴ = brittle

ionic compounds conduct electricity when molten or dissolved in a solution
- charged particles must be able to move freely to carry a current
- ∴ when melted or in an aqueous state, ions can move freely ∴ can conduct electricity

ionic compounds have high melting & boiling points
- attractive forces between the ions is very strong
- a lot of energy is required to overcome the force, ∴ a high temp is needed to break the bonds & form a liquid or gas

metallic bonding

- metal atoms have ↓ electronegativity & ionisation energy
  - ↳ ∴ takes only a small amount of energy to remove the outermost electrons
- metals lose their valence electrons & form a cation
- electrons lost from the bonding become delocalised
  - ↳ ∴ not restricted to one atom, but move in between them



- a metallic bond = the electrostatic attraction between the cations & the 'sea' of delocalised electrons
- they are very strong, depending on
  - ↳ the no. of delocalised e^- (charge of the cation)
  - ↳ size of the cation ∴ no. of protons & inner e^-
  - ↳ how closely packed cations are

STRUCTURE OF METALS

- made of a lattice of cations w/ a sea of delocalised e^-

PROPERTIES OF METALS

high melting and boiling point
- metallic bond = very strong
- ∴ ↑ energy to overcome bonds to allow cations to move freely
- ∴ ↑ temp. required to provide energy

hardness
- very strong ∴ very hard

conduct electricity in all states
- delocalised e^- can move freely between the cations
- ∴ can carry a current

conduct heat (thermal conductivity)
- delocaliced electrons move & transfer heat energy

malleable & ductile
- malleable: able to be hammered into sheets
- ductile: able to be drawn into wires
- metallic bond = non-directional ∴ the cations can be moved without disrupting the strength of the bond

lustre
- soft, shiny light reflected from surface
- delocalised e^- move + reflect light

poor solubility
- metallic bond = very strong ∴ cannot be broken by solvent

BONDING

covalent bonding

- when atoms share a similar electronegativity, neither is 'strong' enough to take the other's e⁻
  - ↳ ∴ share e⁻
- = the electrostatic attraction between positive nuclei & shared pairs of e⁻ of atoms involved
- covalent bonds are directional
  - ↳ a direct 'line' between bonding atoms
- group 17 non-metals (+ H) form 1 cov. bond
- group 16 form 2
- group 15 form 3
- group 14 (+C and Si) form 4
- if more than 1 cov. bond is needed, a double or triple bond is formed
- cov. bonds are very strong + require a lot of energy to be broken
- occur in cov. molecular + cov. network substances

LEWIS DIAGRAMS

- shows the symbol of the element with dots or crosses to represent the valence electrons

① ELEMENTS

·Li　　:Ö·

② MONATOMIC IONS

Lithium ion　·Li → [Li]$^+$

Oxide ion　:Ö· → [:Ö:]$^{2-}$

③ IONIC COMPOUNDS INVOLVING MONATOMIC IONS

Li_2O → ·Li :Ö· → 2[Li]$^+$ [:Ö:]$^{2-}$

CuF_2 → :Cu :F̤· → [Cu]$^{2+}$ 2[:F̤:]$^-$
└ copper (II)

COORDINATE COVALENT BONDS

- both electrons in the shared pair come from the same atom

e.g. Ammonium - NH_4^+

coordinate covalent bond → H:N̈:H (with H above and below)　[H–N–H (H↑ above, H below)]$^+$ ← shows coordinate covalent bond

COVALENT MOLECULAR SUBSTANCES

- most substances formed from non-metals will be covalent molecules (2 or more atoms joined by a cov. bond)
  - ↳ can be molecules of an element - e.g. O_2 or molecules of a compound - e.g. CO_2

LEWIS STRUCTURES

- shows the bonding of atoms in covalent molecules and polyatomic ions

① MOLECULES OF AN ELEMENT

Cl_2　:C̤̈l:C̤̈l:　or　:C̤̈l – C̤̈l:

N_2　:N⁝⁝N:　or　:N≡N:

O_2　Ö::Ö　or　Ō = Ō

② MOLECULES OF A COMPOUND

Ammonia

NH_3 (5e⁻; 1e⁻ × 3 = 3e⁻)　H:N̈:H (lone pair on N)

Methane

CH_4　H:C:H (H above and below C)

③ POLYATOMIC IONS

Ammonium

NH_4　[H:N̈:H (H above and below)]$^+$

Nitrite

NO_2^-　[Ö::N:Ö:]$^-$

[Ö = N – Ö:]$^-$

STRUCTURE + PROPERTIES OF COV. MOLECULES

- the covalent bonds between atoms of a molecule are strong
- the bonds between the molecules are called intermolecular forces, these are much weaker than covalent bonds

low melting & boiling point

- the IMF = relatively weak
  - ∴ require little energy to be broken
- ∴ requires ↓ temp. provides enough energy to melt or boil the substance
- many cov. molecular substances are gases at room temp.

soft

- weak IMF = molecules are easily displaced
- ∴ cov. molecular substances = soft

non-conductor of electricity

- electrons are localised to particular atoms
- there are no ions present in pure form
- ∴ no charged particles that can move to carry a current
- some ionise when they dissolve & would then be able to conduct electricity

COVALENT NETWORK SUBSTANCES

- some substances formed from cov. bonding do not form discrete molecules
- they form a network w/ a growing 3D structure of cov. bonds
  - ↳ e.g. diamond = a network of carbon

PROPERTIES OF COVALENT NETWORKS

high melting & boiling point

- strong cov. bonds require ↑ amount of energy to be broken
- ∴ ↑ temp. is needed to provide enough energy

extremely hard & brittle

- strong cov. bonds = hard to break
- if some are broken, the rest are placed under stress and the network shatters

non-conductors as solids or liquids

- all electrons are localised within bonds or atoms
  - ↳ ∴ there are no free-moving charged particles to conduct electricity

*exception = graphite

- ↳ has covalent bonds in 2 dimensions, forming 3 covalent bonds each - the remaining electron is delocalised and provides the bond between the layers
- ↳ the delocalised electrons are able to carry a current

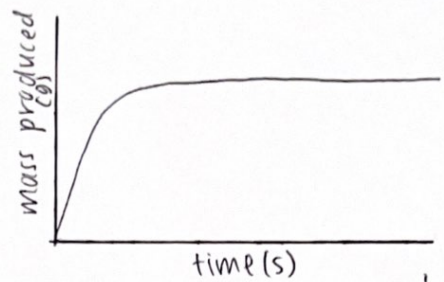
reaction rates

MEASURING RATE OF REACTION

- rate of reaction = amount of products formed in a given time

$$= \frac{\text{amount of substance used or produced}}{\text{time taken}}$$

- measurable quantities:
  - ↳ mass
  - ↳ colour
  - ↳ volume
  - ↳ pH
  - ↳ concentration



↳ the gradient represents the rate of reaction showing how quickly the reactants or products change

COLLISION THEORY

for a chemical reaction to occur:
- the molecules **must collide**
- they must collide w/ **enough energy**
- they must collide w/ **correct orientation**

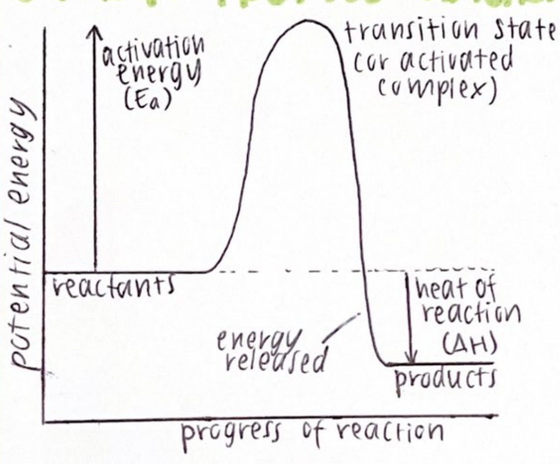
→ the more successful collisions, in a given time, the faster the rate of reaction → changing the rate of a reaction will not change the amount of product formed, only the time it takes to form it

SUCCESSFUL COLLISION
= significant energy + correct orientation so bonds in the reactants to be broken + new bonds to form

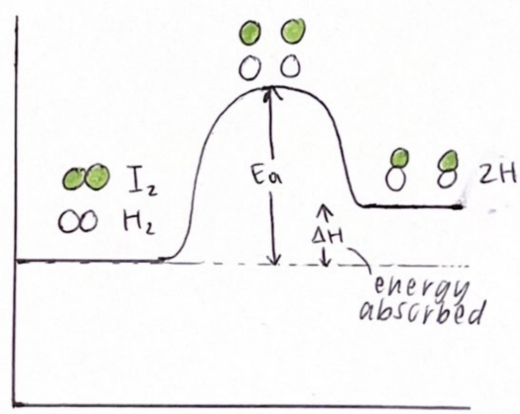
→ the no. of successful collisions depends on:
- ↳ the total no. of collisions/frequency of collisions
- ↳ % of collisions that are successful

UNSUCCESSFUL
= not enough energy or right orientation

ENERGY PROFILE DIAGRAMS



EXOTHERMIC



ENDOTHERMIC

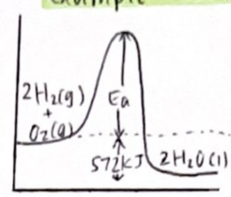
ENERGY PROFILE DIAGRAMS cont.

E_a = activation energy
↳ minimum energy that a collision needs to break the bonds
↳ measured from the enthalpy of the reactants to the top of the peak

transition state/ activated complex = the peak
↳ bond breaking + bond forming both occur ∴ unstable state → the energy released in this stage goes into forming the products

ΔH = enthalpy change
↳ difference in energy between reactants + products
↳ negative = exothermic
↳ positive = endothermic

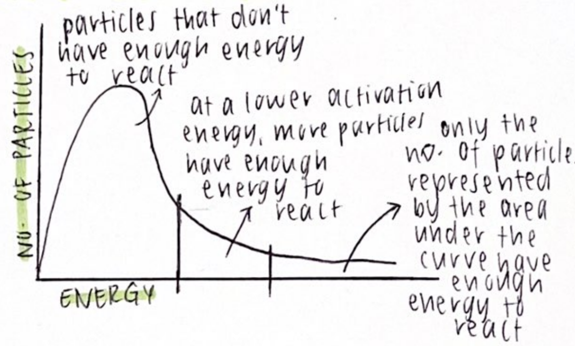
example - exothermic



$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
- heat of reaction $\Delta H = -572kJ$
- activation energy $E_a = E_a kJ$

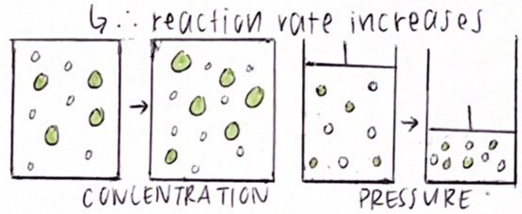
FACTORS THAT AFFECT REACTION RATES

nature of reactants
- if bonds of reactants don't require much energy to break → E_a will be low
- larger no. of particles will have enough energy for successful collision
  ↳ ∴ reaction rate increases

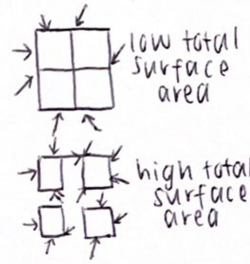


concentration + pressure
- concentration = number of particles in a given volume of a solution
- when concentration ↑, there will be a greater number of reactant particles
  ↳ this increases the frequency (and ∴ total no.) of collisions in a given time
- % of successful collisions remains the same but higher frequency of collisions leads to an increase in the no. of successful collisions
  ↳ ∴ reaction rate increases

- increasing pressure increases the no. of gas molecules in a volume
- this leads to more frequent collisions
  ↳ ∴ reaction rate increases



surface area
- reactions only take place when particles can collide
- in a solid, only exterior particles react
- dividing a solid allows more particles from the insides to be available to react
  ↳ frequency of collisions increases
  ↳ ∴ increase in no. of successful collisions
  ↳ ∴ reaction rate increases



reaction rates cont.

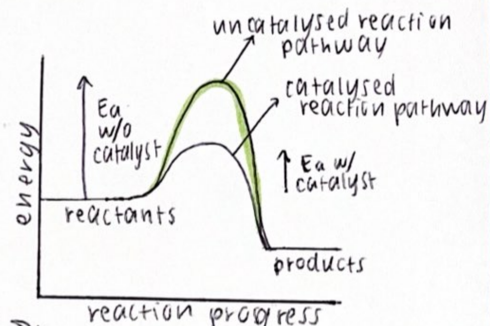
FACTORS THAT AFFECT REACTION RATES cont.

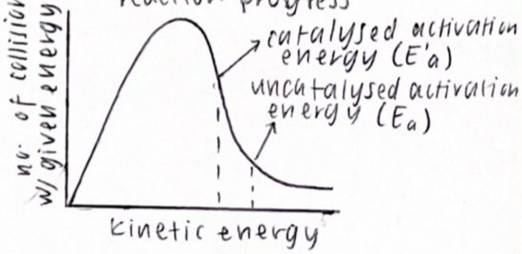
temperature

- at a given temp. particles of a substance will have different amounts of kinetic energy. the average kinetic energy determining the temp.
- the ↑ the temp the ↑ the average kinetic energy
- ∴ more particles will have enough energy to collide successfully
  - ↳ ∴ higher % of collisions are successful
  - ↳ ∴ reaction rate increases
- at higher temp. the particles will move faster due to higher kinetic energy
  - ↳ ∴ more collisions/higher frequency of collisions
  - ↳ however, this increase in speed only has a small affect compared with the increased average kinetic energy

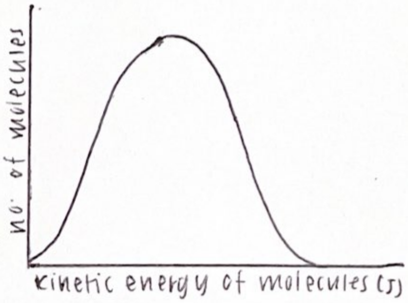
catalysts

- a catalysts: a substance that alters the rate of reaction without being consumed (or used up) in the reaction
- works by providing an alternate pathway for a reaction
- a positive catalyst provides an easier pathway with lower activation energy
  - ↳ ∴ more particles will have sufficient energy for a successful collision
  - ↳ the % of collisions that are successful is increased
  - ↳ ∴ reaction rate increases

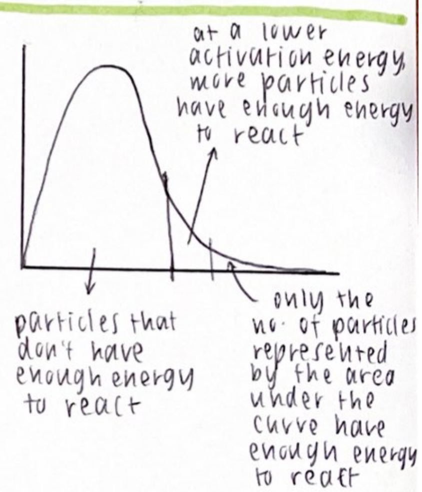


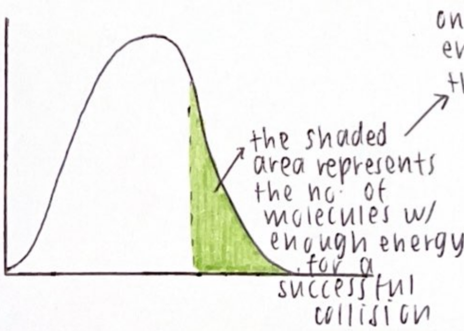


MAXWELL-BOLTZMAN DISTRIBUTION



shows:
- no. of particles present in a chemical reaction
- how much energy particles have
- area under the curve represents the sum of all the particles involved in the reaction

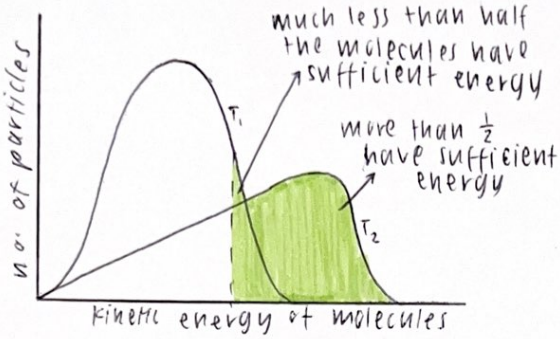




only these particles have enough energy to break the bonds of reactants + have a successful collision

- at a given temp. if the activation energy is lower in one chemical reaction compared to another, then more particles will have sufficient energy to successfully collide + react

MAXWELL-BOLTZMAN DISTRIBUTION CONT.

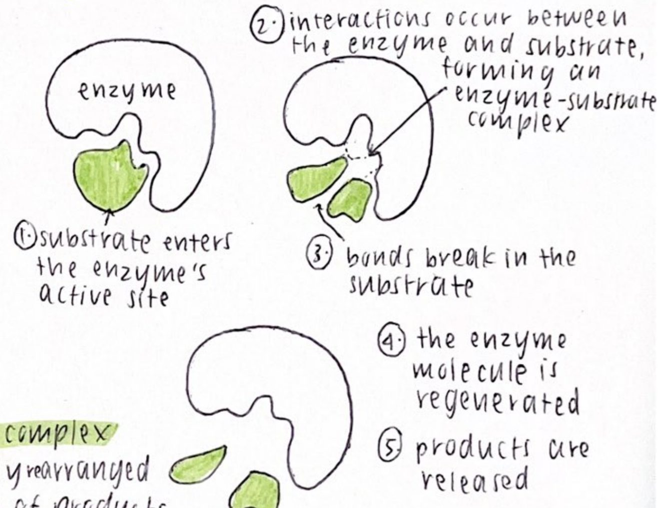


- when the temp. is increased, the distribution of particles with a particular kinetic energy changes
  - ↳ because of increase in kinetic energy
- the graph shows how more particles now have sufficient energy for a successful collision at this increased temp.
  - ↳ because the area under the curve from the activation energy & higher will be bigger

TYPES OF CATALYSTS

enzymes

- large, organic molecules called proteins that act as biological catalysts
- have specifically shaped sections called active sites
  - ↳ interacts w/ the reactants in a chemical reaction
- the reactant(s) that attach to the active site of an enzyme are called substrates
  - ↳ they form weak IMF w/ the active site - forming an enzyme-substrate complex
- the bonds in the substrate are more easily rearranged in this complex - causing quick formation of products (reduced E_a & ↑ rate of reaction)
- the new products are released & the enzyme is left in its original form



- enzymes can produce much faster reaction rates than inorganic catalysts
- enzymes are much more specific in the reactions that they can catalyse
- enzymes are more sensitive to pH & temp. changes than inorganic catalysts

metal nanoparticles

- nanoparticles (1-100nm) have a large surface area
- optimising the large surface area of a catalyst = a large amount of reactants can access the catalyst - having a greater impact on reaction rate
- research into metal nanoparticles is currently occurring

TYPES of CATALYSTS cont.

catalysts in industry

- catalysts speed up/maximise efficiency of slow reactions
- for example: iron catalyst is used in the production of ammonia (which is used in fertilisers)
  - ↳ makes industrial processes more cost effective
- by increasing rate of reaction @ a lower temp., it means less energy is required for the process

catalytic converters

- used in cars to reduce air pollutants
- placed between the engine & the exhaust pipe & contains a mixture of metals over a large surface area
- as toxic products from burning fuels come into contact w/ the catalyst, they are converted to non-toxic gases
  - ↳ $2NO_{(g)} \rightarrow N_{2(g)} + O_{2(g)}$
  - ↳ $2CO_{(g)} + O_{2(g)} \rightarrow CO_{2(g)}$