



**EXTERNAL INFLUENCES**

$4\text{HCl(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{Cl}_2\text{(g)} + 2\text{H}_2\text{O(g)}$

(Exothermic forward, Endothermic reverse)

## LE CHATELIER'S PRINCIPLE

$\text{HCl} + \text{NH}_3 = \text{NH}_4\text{Cl}$

**1. Let's raise the TEMPERATURE**

STRESS  $T \uparrow$  SYSTEM  $T \downarrow$

re-established but shifted to the l.h.s.

**2. Let's raise the PRESSURE**

STRESS  $P \uparrow$  SYSTEM  $P \downarrow$  **MOLES**

re-established but shifted to the r.h.s.

**3. Let's add a little ammonia**

STRESS  $[\text{HCl}] \downarrow$  SYSTEM  $[\text{HCl}] \uparrow$

re-established but shifted to the l.h.s.

## UNIT 3 CHEMISTRY

### SUMMARY NOTES FOR THE VCAA EXAMS

**WRITTEN BY A STUDENT WHO OBTAINED A  
NEAR PERFECT STUDY SCORE**

## FUELS

**Fuel:** A substance that can release chemical energy through a chemical or nuclear reaction

### UNIT CONVERSIONS

1kj (kilojoule)	$10^3\text{J}$
1MJ (megajoule)	$10^6\text{J}$
1GJ (gigajoule)	$10^9\text{J}$
1TJ (tetrajoule)	$10^{12}\text{J}$

**Renewable fuels:** Can be produced at a faster rate than they are consumed e.g biogas

**Cloud point of a fuel:** When the fuel begins to crystallise and is less able to flow

## Fossil Fuels

### Coal:

- source: wood (50% C)—> peat (60% C)—>brown coal (70%C)—>black coal (90% C) \*black coal is the most efficient source as it has the lowest water content—energy is used to evaporate the water
- organic dead matter (sedimentary rock) which is condensed through high heat/pressure over a long period of time (**therefore non-renewable**)
- structure: large molecules of C,H,N,S
- extracted via surfacing/deep mining

### Crude Oil (petroleum):

- a mixture of hydrocarbons (mostly alkanes)
- the useful fuels within crude oil are extracted via fractional distillation (separates substances via their boiling point)
- used for transport and heating
- **non-renewable**—extracted from oil reserves which are not replenished
- extracted via fracking (allows gas to flow to surface)
- **petrodiesel:** produced via fractional distillation of crude oil— less viscous than biodiesel, mainly alkanes

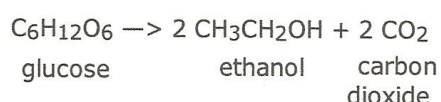
## Natural Gas (Coal Seam Gas):

- a fossil fuel found deep in the earth's crust, made up mainly of methane with small amounts of ethane and propane
- found in:
  - coal deposits where it is bonded to the surface of coal (the is coal seam gas)
  - component of petroleum
  - trapped between layers of rock
- extracted via **fracking**
  1. a well is drilled deep in the deposit
  2. well is encased in concrete to prevent leakage into water supplies
  3. fracking fluid is pumped into wells at high pressure—fractures surrounding coal to allow gas to flow through)
- **liquid petroleum gas:** propane/butane separated from natural gas via fraction distillation, becomes a liquid under high pressure (used in cars)

## Bio Fuels

- renewable energy sources derived from plant materials
- often carbon neutral as CO<sub>2</sub> emissions are used up by plant matter during photosynthesis

### Bioethanol:



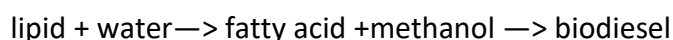
- replaces crude oil
- created by employing enzymes from yeast to convert starch/sugar to ethanol via fermentation

### Biogas:

- a gas released in the breakdown of organic waste by anaerobic bacteria (converts molecules such as carbohydrates/proteins in methane + CO<sub>2</sub>)
- can be used for heating
- manure/farm waste is inserted into a digester containing anaerobic bacteria
- especially useful on farms as the farm waste can be used as the fuel, minimising transport needed

## Biodiesel:

- mixture of esters produced by reacting organic matter (vegetable oil or animal fat) and an alcohol (usually methanol)—process called trans-esterification



- due to polarity of the ester, it attracts water which can inhibit efficient combustion
- can attract water which reduces efficiency of engines
- more viscous than petrodiesel
- high cloud point—more likely to need antifreeze additives than petrodiesel
- if it is made from animal and vegetable fat, its production may be prioritise food production leading to food shortages

## Energy Production

### Production of electrical energy from coal:

*chemical energy (stored in coal) → thermal energy (combustion of coal) → thermal energy used to boil water to create steam → mechanical energy (steam used to power turbine) → electrical energy from generator*

Efficiency: 35%...heat lost to:

- chimney gas
- heat in steam

\*can also use natural gas which is more efficient (40%) or biogas (less efficient)

### Fossil Fuels vs Biofuels:

	Fossil Fuels	Biofuels
Energy content	higher	lower
Renewability	nonrenewable	renewable
Environmental impact	<ul style="list-style-type: none"><li>• air pollution</li><li>• large amounts of greenhouse gas</li><li>• land degradation due to digging</li></ul>	<ul style="list-style-type: none"><li>• smaller carbon footprint (due to the use of photosynthetic organisms)</li><li>• land clearing for biofuels</li><li>• high water usage for crop growth</li></ul>

## Chemical Reactions

**Chemical energy:** stored in the bonds between atoms, results from:

- attraction between electrons and protons
- repulsion's between nuclei
- repulsions between electrons
- movement of electrons
- vibrations/rotations around bonds

**Enthalpy change  $\Delta H$ :** *energy of reactants—energy of products*

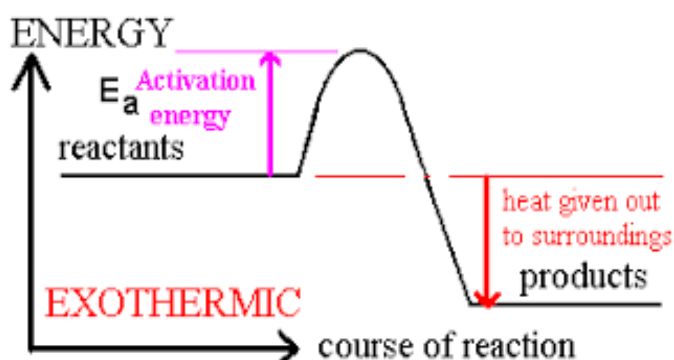
- if  $\Delta H < 0$ , reaction is exothermic
- if  $\Delta H > 0$ , reaction is endothermic
- factors affecting  $\Delta H$ : amount of reactants, temperature, pressure, physical state of reactants/products
- a reaction has a +ve  $\Delta H$  if the strength of bonds in reactants are greater than that of the products
- the difference in energy between reactants/products must be absorbed or released to keep reactants/products at the same temperature

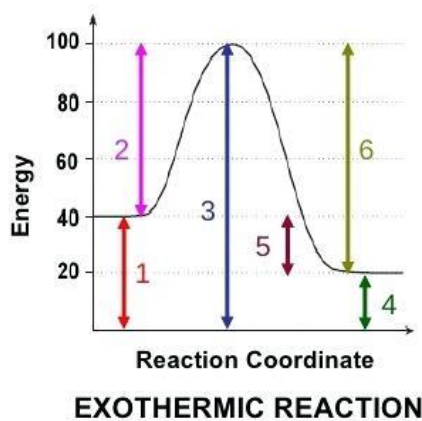
DONT FORGET TO ALWAYS INCLUDE +/- SIGNS!

\* If  $H_2O$  is a liquid in combustion the reaction will have a higher  $\Delta H$  (requires more energy to be a gas)\*

**Energy transfers:**

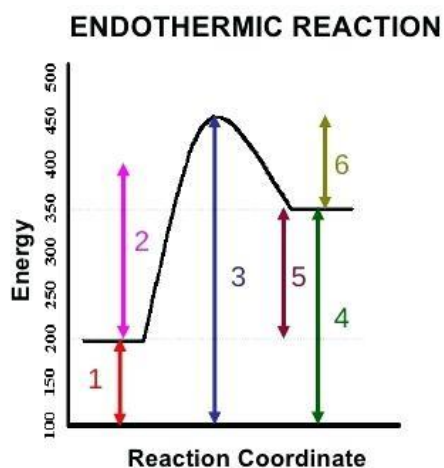
- when bonds are broken, energy is taken from surroundings (this is the activation energy)
- when bonds are formed, energy is released





*When a catalyst is added, 2, 3, and 6 are lowered.*

1. PE of reactants
2. PE of products
3. PE of activated complex
4. activation energy
5. Heat of Reaction,  $\Delta H$
6. activation energy of reverse reaction



## Specific Heat Capacity

- amount of energy required to raise the temperature of 1g of a substance by 1 degrees
- water is 4.18J/G/C due to strong H bonds

$$E = c \cdot m \cdot \Delta T \text{ (joules, g, Celsius)}$$

### Experimental Determination of $\Delta H$ :

0.355g of methanol undergoes combustion and the heat is used to heat 100ml of water,  $\Delta T$  was 17.41.

- determine mass of water— $0.997 \times 100 = 99.7\text{g}$
- energy used to heat water =  $4.18 \times 99.7 \times 17.41 = 7238.19\text{J} = 7.238\text{kJ}$
- number of mols of methanol = 0.011
- divide energy by mols =  $-656\text{KJ/mol}$

### *Reasons why heat transfer is not 100% efficient:*

- heat lost in air (convection)
- evaporation from uncovered beaker
- beaker not insulated

## Gases

- low density
- compress easily
- mix together rapidly

### Kinetic Molecular Theory:

- the volume of gas molecules is negligible compared to the volume of space in which they move
  - gas molecules move in a straight line between frequency collisions
  - all collisions are elastic—no energy lost
  - there are negligible forces acting between molecules
- \* these are ideal gases, the exceptions are at *very high pressure* (forces increase in strength and volume decreases) and *low temperature* (move slowly allowing forces between molecules to operate)

### Volume Conversions

- 1mL = 1cm<sup>3</sup>
- 1000L = 1m<sup>3</sup>

### Pressure:

- a measure of the force applied by gas particles as they collide with walls of the container

$$P = F/A \text{—pascals, newtons, m}^2$$

### Boyles Laws:

$$P \propto \frac{1}{V} \quad P_1 V_1 = P_2 V_2.$$

- pressure will increase as temperature increases (with fixed volume) as particles move faster



## Molar Volume:

- all gases occupy 24.8L for every mol (at 25 degrees and 100kPa)
- $n = V/24.8$

e.g 0.24 mols of N<sub>2</sub> occupies 6L (0.24x24.8)

## Charles Law:

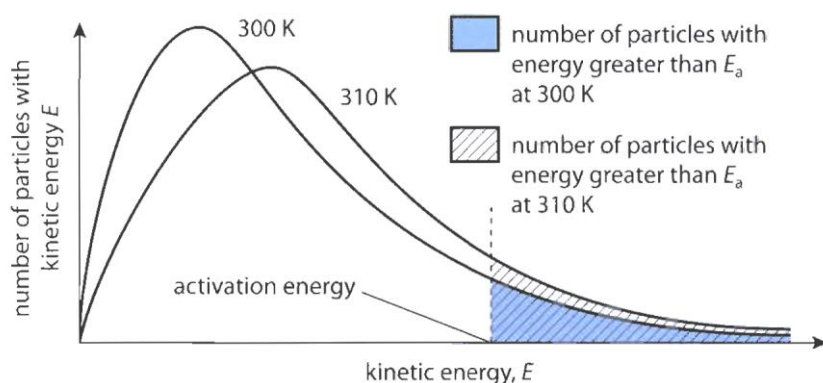
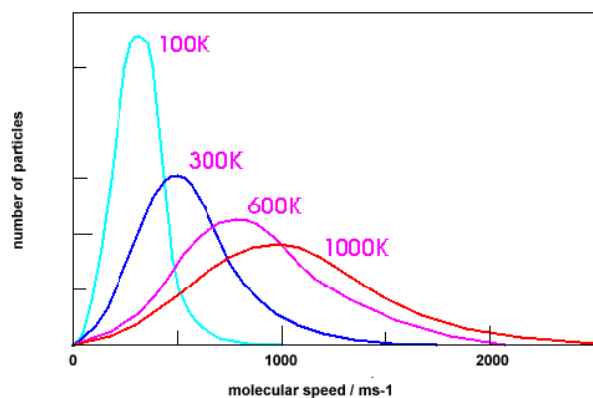
- describes how gases tend to expand when heated
- $V = kT$

## Universal Gas Equation:

- $PV = nRT$  (kPa, L, mols, 8.31, Kelvin (+273))

## Maxwell-Boltzmann Curve:

- at any temperature particles exist with very little energy or very high energy
- only the average kinetic energy changes as temperature increases
- curve shows the proportion of molecules with  $E_a$  (area under the graph is always constant)

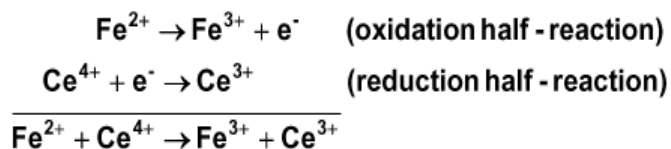


## Redox Reactions

- reactions involving an electron transfer e.g respiration, photosynthesis, combustion

- OILRIG= oxidation is loss, reduction is gain

- oxidants: itself reduced, higher up on electrochemical series



- reductants: itself oxidised, lower on electrochemical series

- in this reaction  $\text{Fe}^{2+}/\text{Fe}^{3+}$  and  $\text{Ce}^{4+}/\text{Ce}^{3+}$  are **conjugate pairs**

### Oxidation Number Rules:

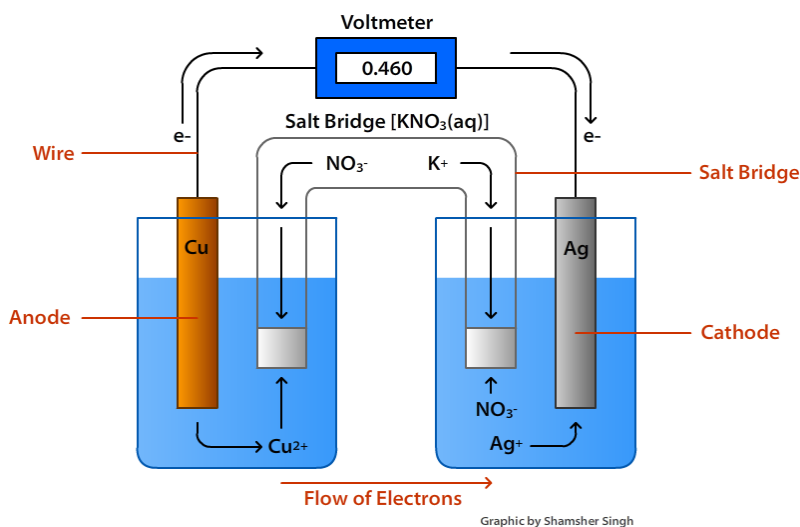
- **free elements:** 0 e.g  $\text{O}_2$
- **ionic compounds:** same as their valency e.g  $\text{SO}_4^{2-}$   $\text{O} = -2$   $\text{S} = +6$
- **exceptions:**
  - $\text{O}$  is -1 in peroxides such as  $\text{H}_2\text{O}_2$  and  $\text{BaO}_2$
  - $\text{H}$  is -1 in metal hydrides such as  $\text{NaH}$  and  $\text{CaH}_2$
  - the most electronegative element in a compound has a negative oxidation number e.g  $\text{F}_2\text{O}$   $\text{F} = -1$   $\text{O} = +2$

Increase in oxidation number indicates an element has been oxidised

### Writing Half Equations:

- key elements—> oxygen ( $\text{H}_2\text{O}$ )—> Hydrogen ( $\text{H}^+$ )—> electrons—>states
- e.g  $2\text{NO}_3^- \rightarrow \text{N}_2\text{O}$ 
  - $2\text{NO}_3^- \rightarrow \text{N}_2\text{O} + 5\text{H}_2\text{O}$
  - $10\text{H}^+ + 2\text{NO}_3^- \rightarrow \text{N}_2\text{O} + 5\text{H}_2\text{O}$
  - $10\text{H}(\text{aq}) + 2\text{NO}_3^-(\text{aq}) + 8\text{e}^- \rightarrow \text{N}_2\text{O}(\text{g}) + 5\text{H}_2\text{O}(\text{l})$

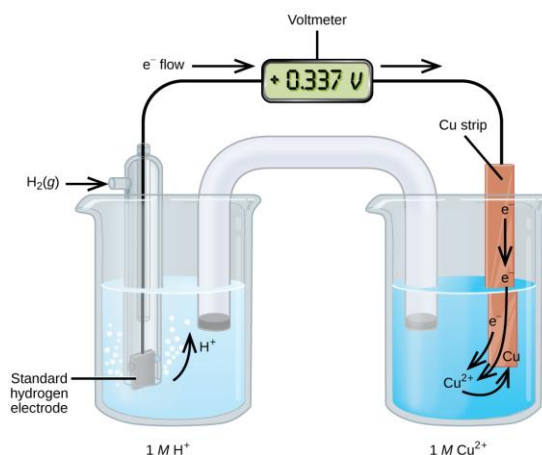
## GALVANIC CELLS



- convert chemical energy into electrical energy (exothermic)
- require a negative gradient on the electrochemical series
- batteries are units of galvanic cells linked together
- requires a salt bridge that won't take part in the reactions but provides ions to balance out changes that accumulate e.g KNO<sub>3</sub>
  - cations move to cathode (+)
  - anions move to anode (-)
- Cathode: positive, reduction, mass accumulates
- Anode: negative, oxidation, mass lost

## Gas electrodes:

- uses inert electrodes (Pt or Cu)



## Saltbridge:

- completes circuit by allowing ionic conduction to maintain electrical neutrality in each half cell
- must be ionic, soluble in water, inert
- usually KNO<sub>3</sub> or KOH

## Electrochemical series:

- Potential difference: under standard conditions (100kPa, 1M concentration, 25 degrees)
  - compared to standard hydrogen half cell
  - indicates the volts of current which will be produced
  - $E = E(\text{oxidant}) - E(\text{reductant})$
- some reactions may not occur as they are too slow

## Primary Cells:

- disposable, cannot be recharged e.g torch/remote
- cannot be recharged because the products slowly migrate from electrodes or are consumed by side reactions
- design promotes the removal of products from electrodes
- they cause harmful chemical to be put in environment after disposal
- e.g dry cell, button cell

- **design features:**

- reductant is a metal
- electrolytes concentrated in paste/gel
- a porous 'separator' used rather than a salt bridge to allow ion exchange
- products are removed from electrodes (usually soluble)

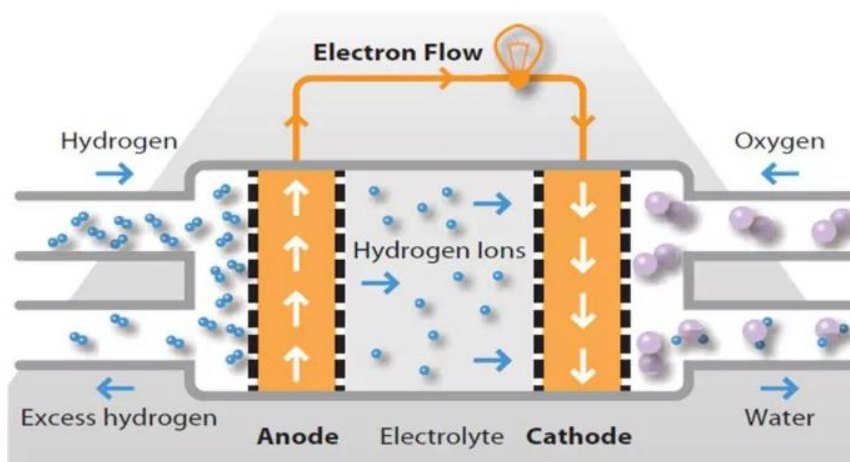
## Secondary Cells:

- rechargeable as solid products adhere to electrodes
- recharging:
  - reactions are reversed by connecting to a power source slightly higher (due to energy lost in transformation such as heating wire) than the potential difference (becomes an electrolytic cell) to convert chemical to electrical energy
  - anode becomes positive (attaches to positive end of power source)
  - cathode becomes negative (attaches to negative end of power source)

## Battery Life:

- the performance of a battery measures in the number of charge-discharge cycles before a battery becomes unusable
- factors leading to battery decrease:
  - loss of active materials to side reactions
  - formations of other chemicals that impede functioning of the cell
  - impurities of electrodes that can react with active materials
- temperature: causes faster rate of deterioration due to faster side reactions however low temperatures deliver less electric charge

## Fuel Cells



- a type of galvanic cell that doesn't need recharging as there is a continuous supply of reactants
- must be discarded once equilibrium is achieved
- provide energy for forklifts, power plants, cars
- generally 40-60% efficient (this can be increased to 80% if the steam they produce is used to power turbines)
- have a higher efficiency than thermal power stations as chemical energy is directly transformed to electrical energy
- **hydrogen economy: proposed system of using only hydrogen for fuel**— good for the environment as very low emissions (only emits water, heat and very small amounts of NO<sub>2</sub>)—could replace internal combustion engines

### Reactions:

Anode:  $\text{H}_2 + \text{OH}^- \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$  (basic)

$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$  (acidic)

Cathode:  $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$

$\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2\text{O}$  (acidic)

Overall:  $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$

- hydrogen splits into H<sup>+</sup> and e<sup>-</sup> and reacts with OH<sup>-</sup> in electrolyte to form water
- O<sub>2</sub> reacts with water to replenish OH<sup>-</sup> in electrolyte, PH remains constant

### Balancing alkaline half equations:

- $O_2 \rightarrow H_2O$
- balance normally using KOH —  $O_2 + 4H^+ + 4e^- \rightarrow H_2O$
- add  $OH^-$  to cancel out  $H^+$  —  $O_2 + 4H^+ + 4OH^- + 4e^- \rightarrow H_2O + 4OH^-$  (hydroxide and hydrogen form water)
- $4e^- + O_2 + 2H_2O \rightarrow 4OH^-$

### Fuel Cell Electrodes:

- conducting
- inert (usually Pt)
- catalytic
- porous to allow  $H_2$  and  $O_2$  to come in contact with ions in electrolyte (this also increases surface area for reaction)

### Catalysts:

- used to increase rate of reaction and current produced
- platinum is anode catalyst
- nickel is cathode catalyst

### Electrolyte:

- either a strong acid (HCl) or strong base (KOH)
- semi-permeable to allow only reductant in—if it were permeable to both, they would react in electrolyte and thermal energy would be produced

## Hydrogen as a Fuel

- higher energy content than most fossil fuels
- produced zero harmful emissions
- often produced through steam reforming of methane, therefore non renewable but can also be extracted from biogas and hydrolysis of water which is renewable
- difficult to store: liquid hydrogen requires lots of energy to keep as a liquid, compressed hydrogen takes up very high volumes
- unsafe: burns rapidly

Advantages	Disadvantages
more efficient energy conversion than thermal power plants	require constant energy supply
no carbon emissions	expensive as technology is still developing
don't need to be recharged	hydrogen is mainly sourced from fossil fuels, non renewable
can use a variety of fuels	hard to store hydrogen

### Applications:

- electroplating:
  - aqueous solution of cations of plating metal, cathode is the substance being plated



# Rates of Reaction

## Collision Theory:

Particles must collide with sufficient energy and in correct orientation to undergo fruitful collisions

**Surface Area:** an increase in surface area means that more reactant particles are exposed which increases the frequency of collisions

**Concentration/Pressure:** increased mol of reactants per volume therefore closer proximity which causes higher collision frequency

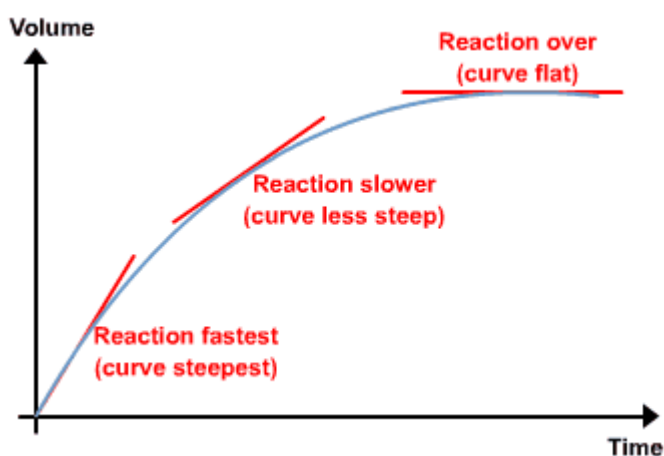
**Temperature:** average kinetic energy of reactants increases (more likely to have  $E_a$ ) and also increases speed of movement, causing more frequent collisions

**Catalyst:** provides an alternative pathway with lower activation energy, more particles likely to have  $E_a$  for fruitful collision

- can be either *homogenous (same physical state)* or *heterogeneous (different physical state)*
- **adsorption** (*forms bonds with molecule to weak intramolecular bonds*) → **reaction** → **desorption** → *products released from active site*

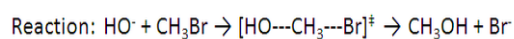
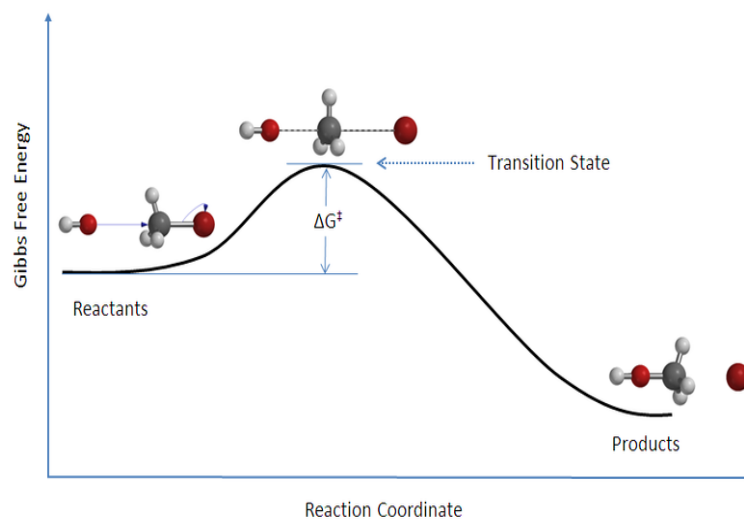
## Measuring ROR:

change in concentration per unit time (M/s) or colour change, pH



## Transition State:

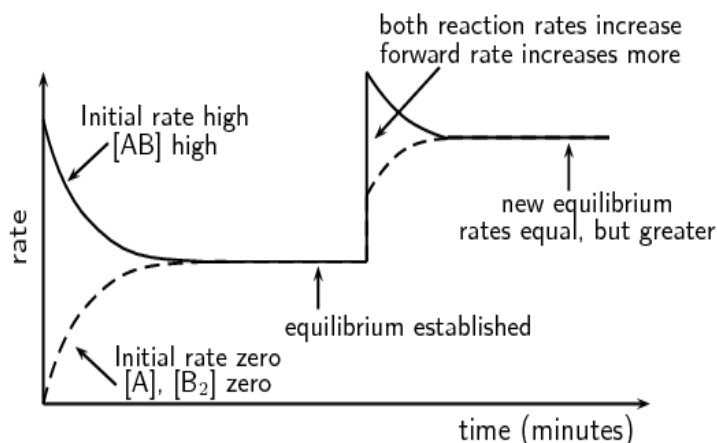
*The new arrangement of atoms once the activation energy has been absorbed—occurs at the stage of maximum potential energy*



## Open/Closed Systems:

- open—matter and energy can be exchanged with the surroundings e.g a bushfire
- closed—only energy exchanged with surrounding e.g submarine

## Equilibrium



*A dynamic state of equilibrium occurs when the rate of the forward and backward reactions are equal—the system will stay at equilibrium unless there is a change to the environment*

- concentration of products and reactants are constant at equilibrium (but not necessarily the same)

### Concentration Fraction ( $K_c$ )

- has a different value at each stage of the reaction but is constant at equilibrium ( $K_c$ )
- $K_c = \frac{[\text{products}]}{[\text{reactants}]}$ 
  - the larger  $K_c$ , the greater the proportion of reactants that have been converted to products
  - $K_c > 10^4$  = forward reaction favoured
  - $K_c < 10^{-4}$  = backward reaction favoured



$$K_c = \frac{[A]^w[B]^x}{[C]^y[D]^z}$$

\*if it is between these values there is significant concentration of both reactants and products

- $K_c$  is unique and will change when the temperature changes
- exothermic reactions— $K$  decreases as temperature increases
- endothermic reactions— $K$  increases as temperature increases

ICE Tables—use when you have initial/final conc

	$\text{HA(aq)} \rightleftharpoons \text{H}^+(\text{aq}) + \text{A}^-(\text{aq})$		
Initial concentration (M)	0.150	0	0
Change (M)	$-x$	$x$	$x$
Equilibrium concentration (M)	$0.150 - x$	$x$	$x$

### Manipulating Kc in Equations:

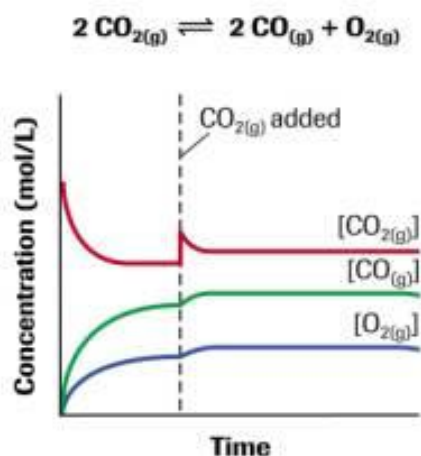
- ☐ *Equation reversed: reciprocal*
- ☐ *Coefficients halved: raise to power of 0.5*
- ☐ *Equations added: multiply*

## Le Chatelier's Principle

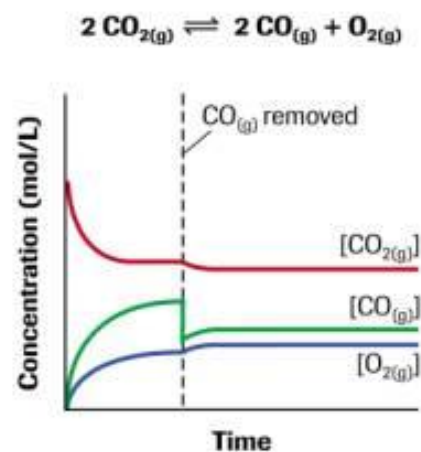
- if an equilibrium system is subjected to a change, the system will adjust itself to partially oppose the change
  - decreased pressure/concentration will cause reaction to favour side with most mols
  - increase concentration of reactants will drive reaction backwards
  - increase in temperature will favour endothermic reaction
  - removing a reactant will favour forwards reactions
  - catalyst will increase both forward and backwards reactions

\*when drawing graphs remember that concentration will increase/ decrease according to mol ratios

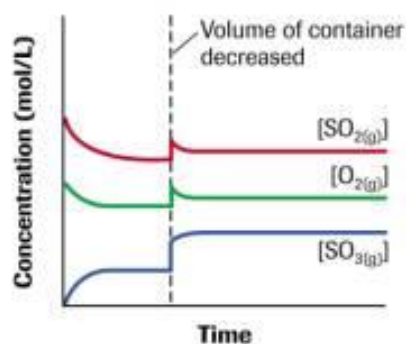
### Reactant Added:



### Removing Product:



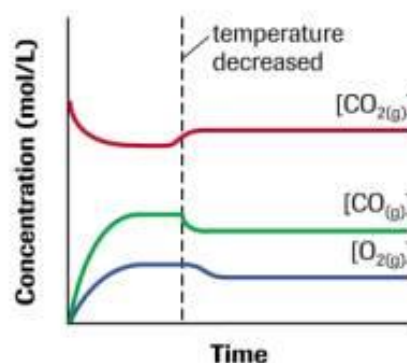
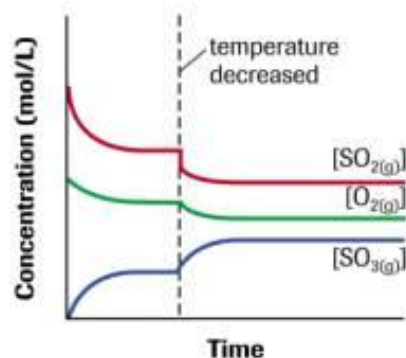
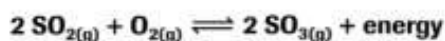
Changing pressure: \*adding an inert gas has no effect\*



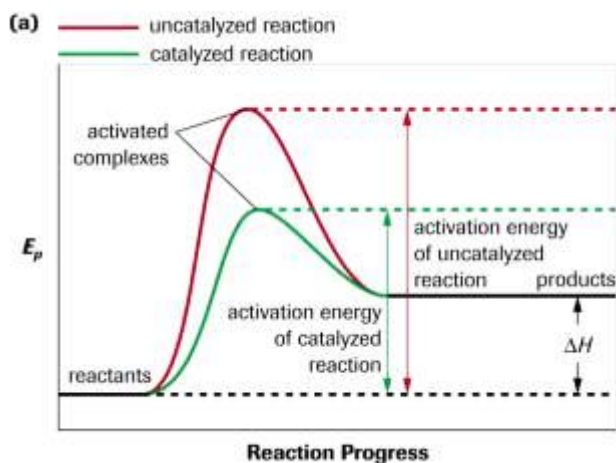
Dilution:

All concentrations will sharply decrease at the same time. Reaction proceeds in the direction that produces more particles.

Temperature Change:



Catalyst:



## Optimising Yield

- needs a balance of high reaction rates and high equilibrium yield
- **reaction rate:** high concentration, high temp, high surface area, catalyst
- **high equilibrium yield:** low temp for exothermic, high temp for endothermic, addition of excess reactants, removal of product as it forms
- percentage yield:  $\text{actual yield} / \text{theoretical yield}$

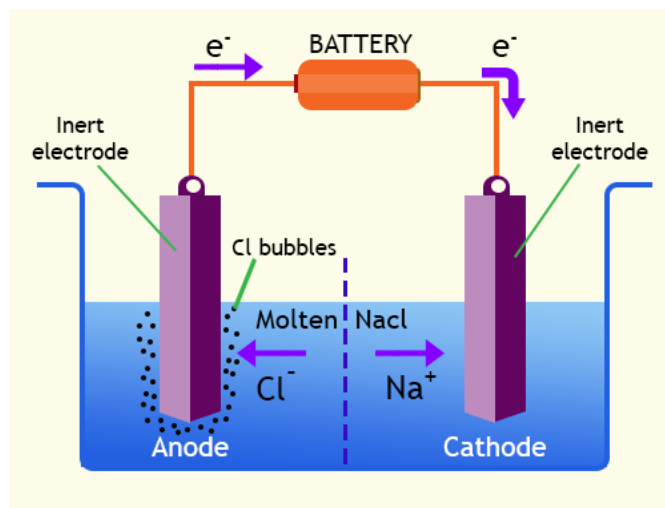
## Electrolysis

converting electrical energy into chemical energy—using a power source to allow non-spontaneous reactions

- usually takes place in one container as a non-spontaneous reaction is involved

### Molten NaCl

- must be molten as  $\text{H}_2\text{O}$  would be preferentially oxidised
- cathode (-):  $\text{Na}^+ + \text{e}^- \rightarrow \text{Na(l)}$ —this is connected to negative power supply which pushes electrons to this electrode
- anode (+):  $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$ —connected to positive power supply which pushes its electrons to the cathode



\*always list out all species present to determine strongest oxidant and reactant (this can be water in aqueous solutions) except for the cathode material

### Faraday's Laws

$$Q = I \times T \text{ (coulombs, current (amps), time (seconds))}$$

- the charge of 1 mol of electrons = 96500C

e.g A silver plating cell operates at 30A for 20 minutes, what mass of silver is produced?

- $Q = 30 \times 20 \times 60 = 3.6 \times 10^4 \text{ C}$
- $n(\text{e}) = 36000 / 96500 = 0.373 \text{ mol}$
- $n(\text{Ag}) = n(\text{e})$
- $m(\text{Ag}) = 40.3 \text{ g}$