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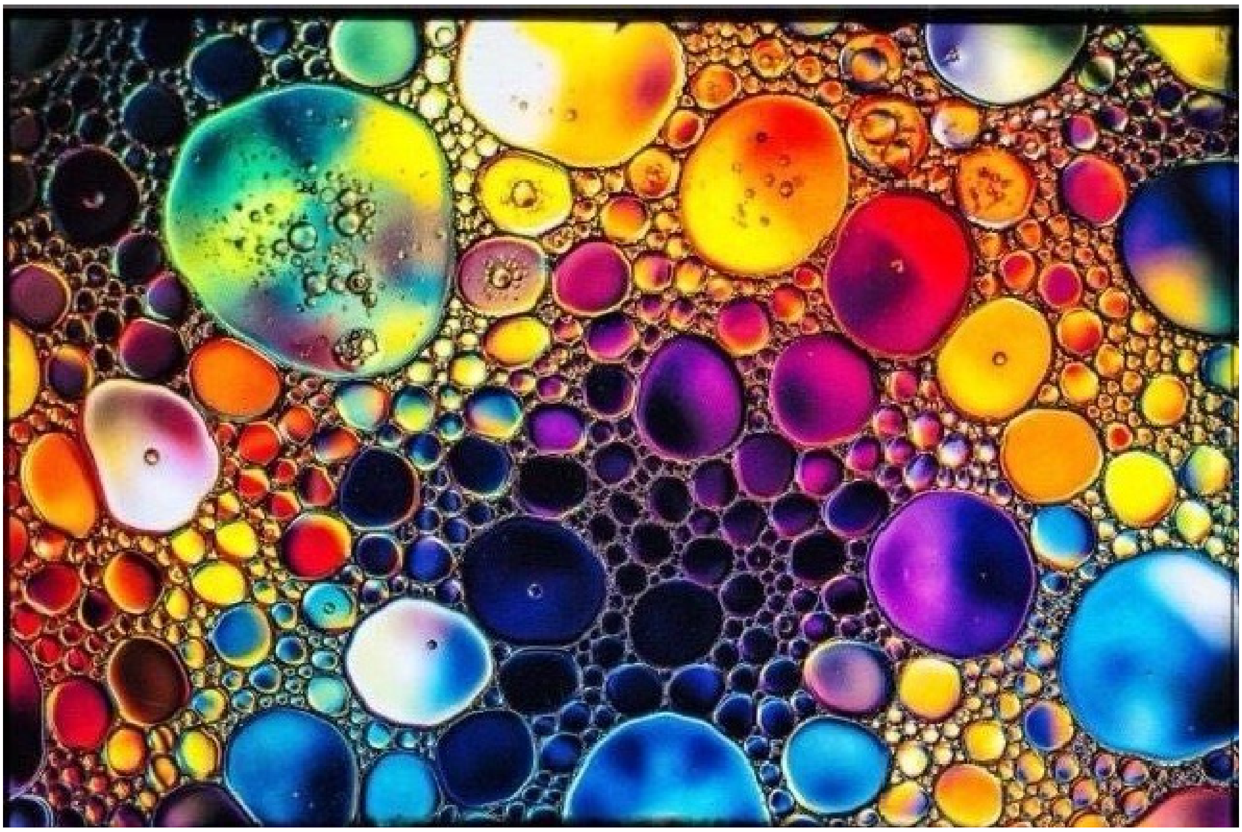
THE SCHOOL FOR EXCELLENCE

UNIT 3 CHEMISTRY



SUMMARY NOTES FOR THE VCE EXAMS

WRITTEN BY A STUDENT WHO OBTAINED A NEAR PERFECT STUDY SCORE

BONUS AOS-2 EXAM & DETAILED ANSWERS AT THE BACK (WRITTEN BY TSFX)

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FUELS

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

UNIT CONVERSIONS

1kj (kilojoule)	10^3J
1MJ (megajoule)	10^6J
1GJ (gigajoule)	10^9J
1TJ (tetrajoule)	10^12J

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 CO2 emissions are used up by plant matter during photosynthesis

Bioethanol:

$$\underset{\text{glucose}}{C_6H_{12}O_6} \longrightarrow 2\,\underset{\text{ethanol}}{CH_3CH_2OH} + 2\,\underset{\text{carbon dioxide}}{CO_2}$$

- 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 + CO2)
- 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

lipid + water—> fatty acid +methanol —> biodiesel

- due to polarity of the ester, it attracts water which can inhibit efficient combustion
- can attract water which reduces efficiency of engines
- more vicious than petrodiesel
- high cloud point—more likely to need antifreeze additives than petrodiesel
- is it is made from animal and vegetable fat, ist 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	• air pollution • large amounts of greenhouse gas • land degradation due to digging	• smaller carbon footprint (due to the use of photosynthetic organisms) • land clearing for biofuels • high water usage for crop growth

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 ΔH: ***energy of reactants—energy of products***

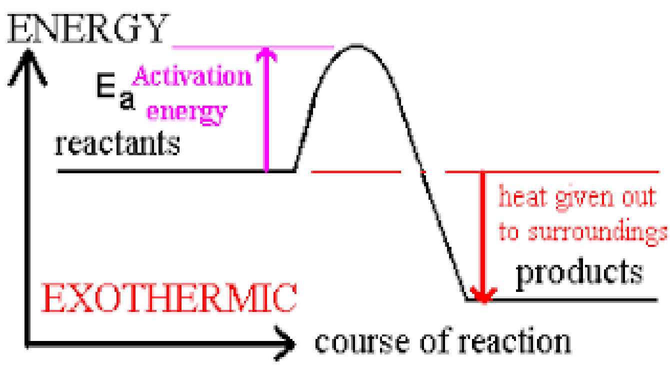
- if ΔH <0, reaction is exothermic
- if ΔH >0, reaction is endothermic
- factors affecting ΔH: amount of reactants, temperature, pressure, physical state of reactants/products
- a reaction has a +ve ΔH if the strength of bonds in reactants are greater than that of the products
- the difference in energy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

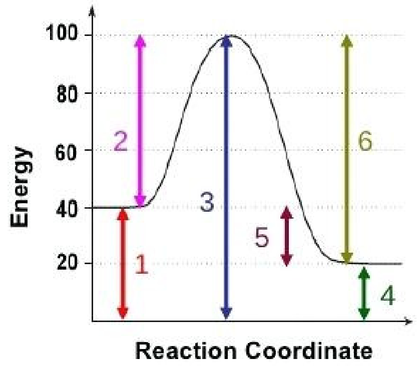
DONT FORGET TO ALWAYS INCLUDE +/- SIGNS!

* If H2O is a liquid in combustion the reaction will have a higher ΔH (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

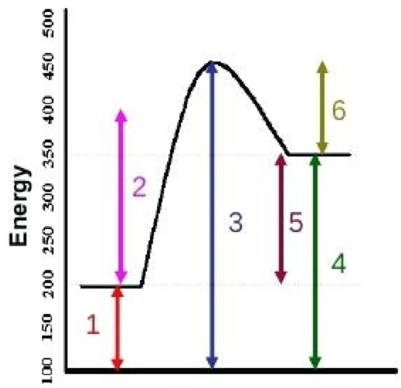




EXOTHERMIC REACTION

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

ENDOTHERMIC REACTION



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

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

$E = c*m* \Delta T$ (joules, g, Celsius)

Experimental Determination of ΔH:

0.355g of methanol undergoes combustion and the heat is used to heat 100ml of water, ΔT was 17.41.

- ➢ determine mass of water—0.997x100 = 99.7g
- ➢ energy used to heat water = 4.18x99.7x17.41 = 7238.19J =7.238kJ
- ➢ number of mols of methanol = 0.011
- ➢ divide energy by mols = -656Kj/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 in 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 = 1cm3
- 1000L = 1m3

Pressure:

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

P=V/A—pascals, newtons, m2

Boyles Laws:

$$P \propto \frac{1}{V} \qquad P_1V_1 = P_2V_2.$$

- 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 N2 occupies 6L (0.24x24.8)

Charles Law:

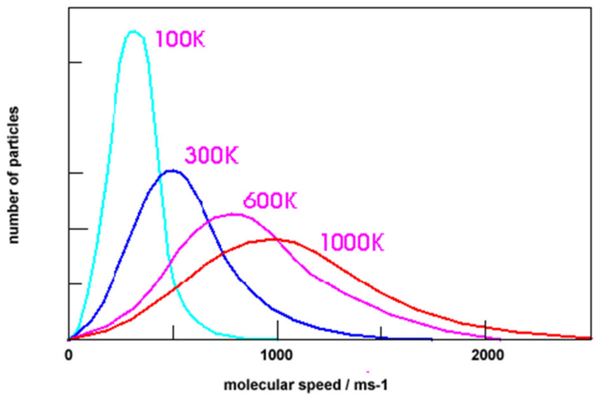
- describes how gases tend to expand when heated
- V = kT

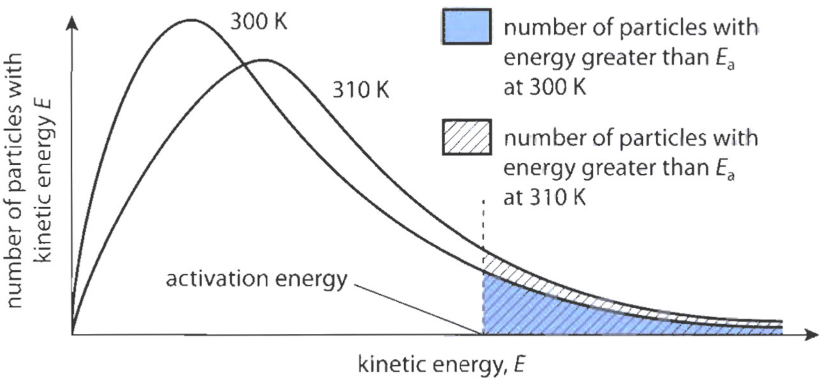
Universal Gas Equation:

- 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 Ea (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

$$
\begin{array}{ll}
Fe^{2+} \rightarrow Fe^{3+} + e^{-} & \text{(oxidation half - reaction)} \\
Ce^{4+} + e^{-} \rightarrow Ce^{3+} & \text{(reduction half - reaction)} \\
\hline
Fe^{2+} + Ce^{4+} \rightarrow Fe^{3+} + Ce^{3+} &
\end{array}
$$

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

Oxidation Number Rules:

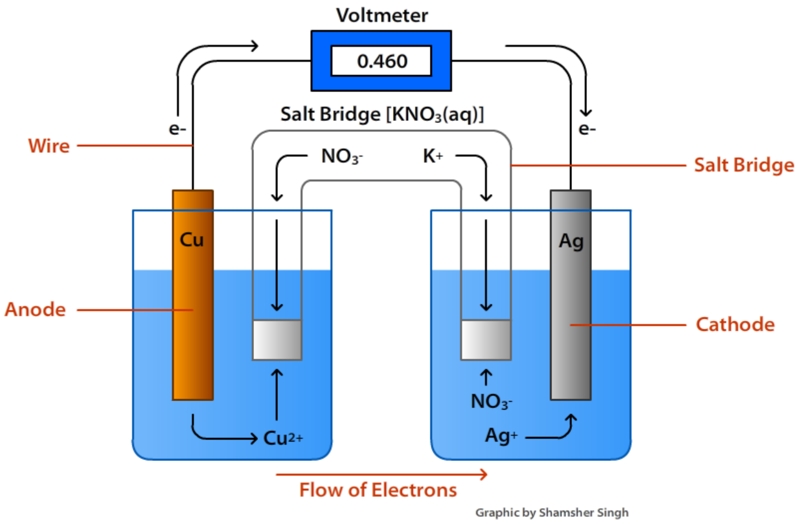
- ***free elements:*** *0 e.g O_2*
- ***ionic compounds:*** *same as their valency e.g SO_4^{2-} O=-2 S=+6*
- *exceptions:*
  - *O is -1 in peroxides such as H_2O_2 and BaO_2*
  - *H is -1 in metal hydrides such as NaH and CaH_2*
  - *the most electronegative element in a compound has a negative oxidation number e.g F_2O F=-1 O=+2*

Increase in oxidation number indicates an element has been oxidised

Writing Half Equations:

- key elements—> oxygen (H_2O)—> Hydrogen (H^+)—> electrons—>states
- e.g $2NO_3^-$ —> N_2O
  - ➢ $2NO_3^-$ —> N_2O+ $5H_2O$
  - ➢ 10 H^+ $2NO_3^-$ —> N_2O+ $5H_2O$
  - ➢ 10 H(aq)+ $2NO_3^-$(aq)+ 8e- —> N_2O(g)+ $5H_2O$(l)

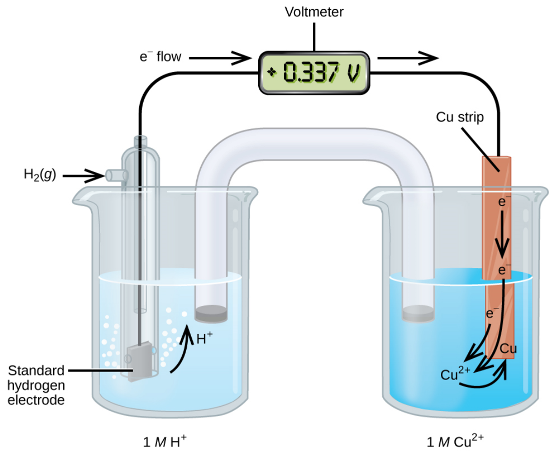
GALVANIC CELLS



- 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 KNO3
  - ➢ 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 KNO3 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(oxidant)-E(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)

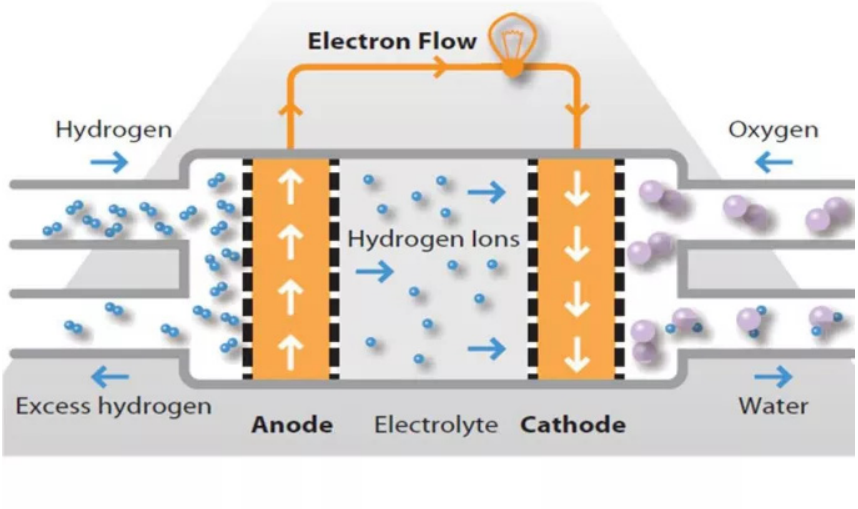
Secondary Cells:

- 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) then the potential difference (becomes a 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:

- desire 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 NO2)—could replace internal combustion engines

Reactions:

Anode: H2 + OH- —> 2H20 + 2e- (basic)

H2—> 2H+ +2e- (acidic)

Cathode: O2 + 2H20 +4e- —> 4OH-

O2+ 2H+ +2e- —>H2O (acidic)

Overall: H2+O2—>H2O

- hydrogen splits into H+ and e- and reacts with OH- in electrolyte to form water
- O2 reacts with water to replenish OH- in electrolyte, PH remains constant

Balancing alkaline half equations:

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

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 ower 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

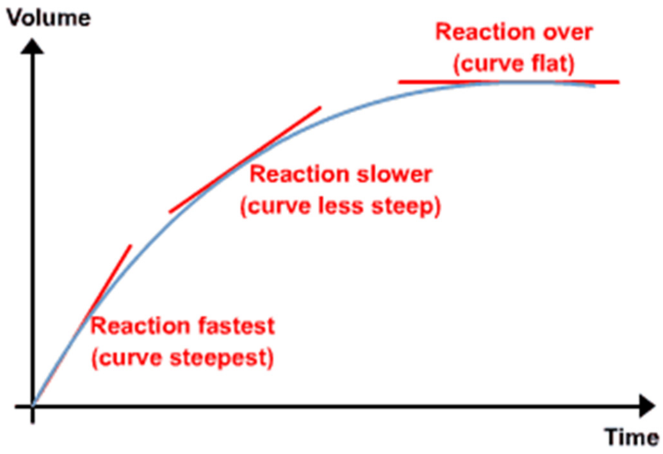
Temperature: average kinetic energy of reactants increases (more likely to have Ea) and also increases speed of movement, causing more frequent collisions

Catalyst: provides an alternative pathway with lower activation energy, more particles likely to have Ea 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*

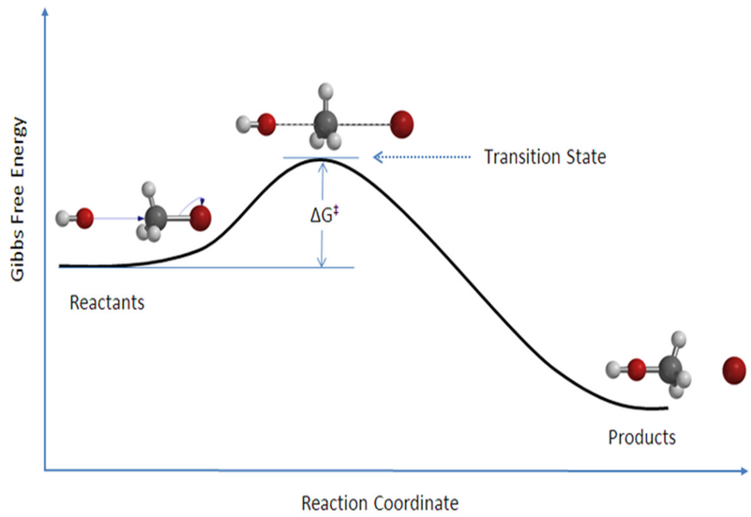
Measuring ROR:

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



Transition State:

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

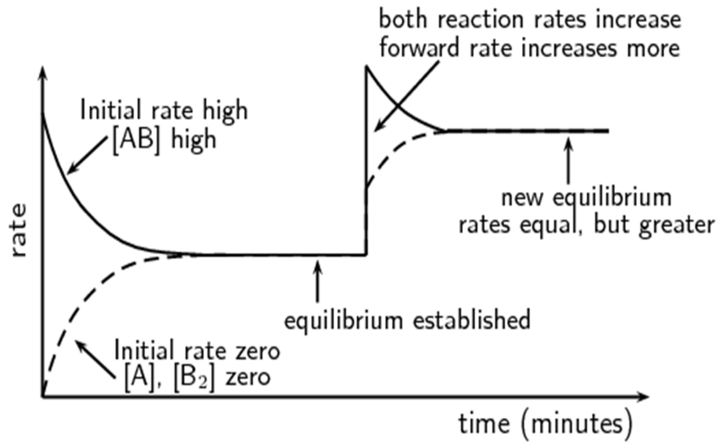


Reaction: $HO^- + CH_3Br \rightarrow [HO\text{---}CH_3\text{---}Br]^{‡} \rightarrow CH_3OH + Br^-$

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 or 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 (Qc)

- has a different value at each stage of the reaction but is constant at equilibrium (Kc)
- Qc= [products]/[reactants]
  - the larger Kc, the greater the proportion of reactants that have been converted to products
  - Kc>10^4 =forward reaction favoured
  - Kc <10^-4 =backward reaction favoured

$wA + xB \rightleftharpoons yC + zD$

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

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

- ➢ Kc is unique and will change when the temperature changes
- ➢ exothermic reactions—K decreases as temperature increase
- ➢ endothermic reactions—K increases as temperature increases

ICE Tables

Use when you have initial/final conc

	$HA(aq)$	$\rightleftharpoons H^+(aq)$	$+ A^-(aq)$
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

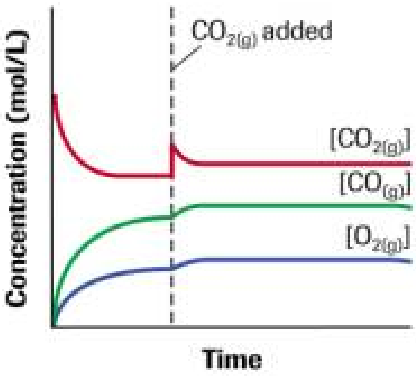
Le Chatelier's Principle

- 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 site 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

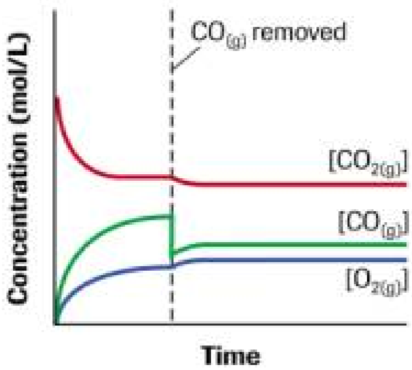
Reactant Added:

$$2\,CO_{2(g)} \rightleftharpoons 2\,CO_{(g)} + O_{2(g)}$$



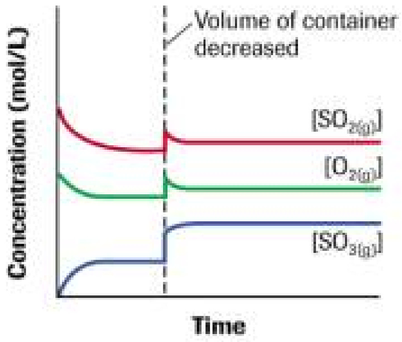
Removing Product:

$$2\,CO_{2(g)} \rightleftharpoons 2\,CO_{(g)} + O_{2(g)}$$



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

$2\,SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\,SO_{3(g)} + \text{energy}$

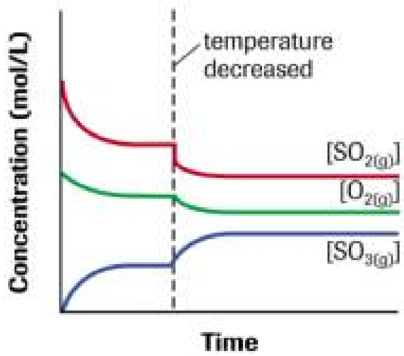


Dilution:

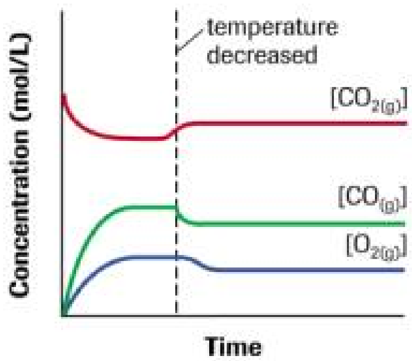
All concentrations will sharply decrease at the same time. Reaction proceeds in the direction that produces more particles.

Temperature Change:

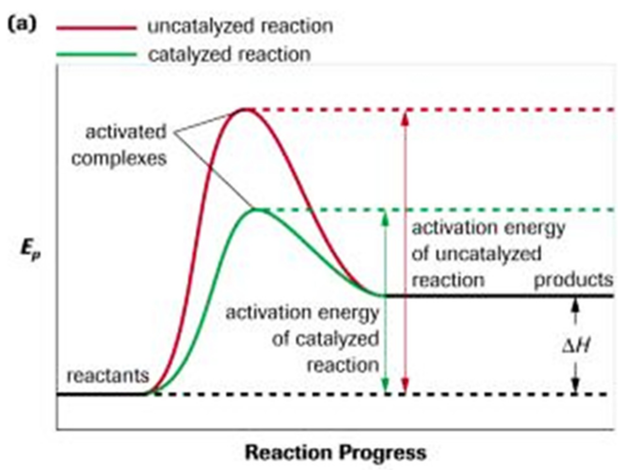
$2\,SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\,SO_{3(g)} + \text{energy}$



$CO_{2(g)} + \text{energy} \rightleftharpoons 2\,CO_{(g)} + O_{2(g)}$



Catalyst:



Optimising Yield

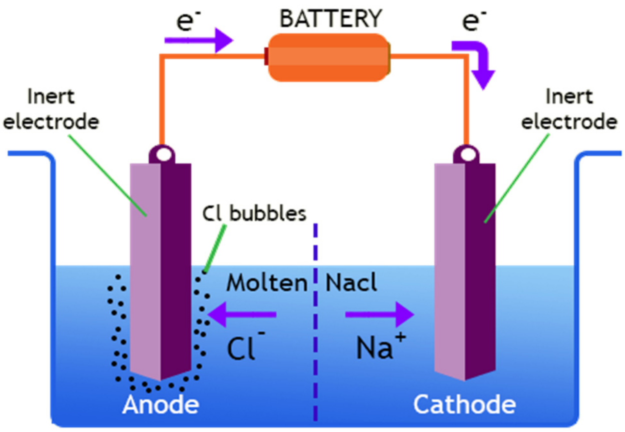
- needs a balance of high reaction rates and high equilibrium yield
- ***reaction rate:*** high concentration, high temp, high surface area, catalyst
- ***high equilibrium yield:*** low temp for exothermic, high temp for endothermic, addition of excess reactants, removal of product as it forms
- percentage yield: actual yield/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 H2O would be preferentially oxidised
- cathode (-): Na+ + e- —> Na(l)—this is connected to negative power supply which pushes electrons to this electrode
- anode (+): 2Cl- —> Cl2 +2e- —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

F = Faraday's Constant = Charge on 1 mole of electrons = 96,500 C

The charge, Q, on a given number of mole of electrons is determined by the following rule:

$$Q = n(e^-) \times F$$

The mass of substance produced or consumed at an electrode is directly proportional to the total charge (quantity of electricity) that is passed through a system.

$$m \propto Q$$

mass (g) charge (C)

Anything that increases the total charge moving through the cell will increase the amount of substance consumed or produced at the electrodes.

$$Q = It$$

charge (coulombs) current (amps) time (seconds)

The charge (Q) that passes through a cell is dependent on the number of electrons transferred in a given time.

As $Energy(J) = VIt$ and $It = Q$ then $Energy(J) = QV$

When the same amount of electricity is passed through different electrolytes, the mass of the substances deposited or consumed are inversely proportional to the charge carried by the equivalent metal ions.

$$Amount\ (in\ mole) \propto \frac{1}{The\ charge\ on\ the\ metal\ ion}$$

Q= I x T (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 x 20 x 60 =3.6 x10^4 C
- n(e)= 36000/96500 =0.373mol
- n(Ag) = n(e)
- m(Ag) = 40.3g

THE SCHOOL FOR EXCELLENCE (TSFX)

VCE CHEMISTRY UNIT 3 – AREA OF STUDY 2

WRITTEN EXAMINATION PAPER – 2023

Reading Time: 15 minutes
Writing Time: 2 hours 30 minutes

QUESTION AND ANSWER BOOK

Student Number:				Letter

Structure of Book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	10	10	90
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials Supplied

- Question and answer book of 39 pages.
- Data book
- Answer sheet for multiple choice questions.

Instructions

- Write your **student number** in the space provided above on this page.
- All written responses must be in English.

At the End of the Examination

Place the answer sheet for multiple-choice questions inside the front cover of this book.

Students are **NOT** permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

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SECTION A – MULTIPLE CHOICE QUESTIONS

Instructions for Section A

Answer all questions in pencil on the answer sheet provided for multiple choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1, an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

QUESTION 1

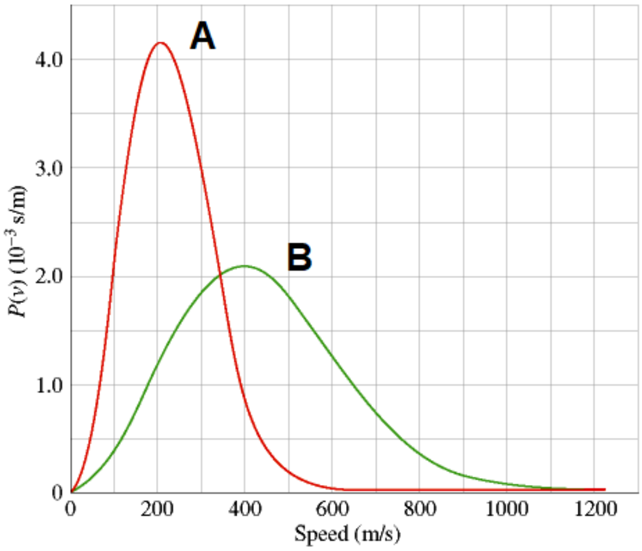
Potassium chlorate decomposes according to the following reaction:

$$2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$$

The rate of formation of oxygen is 0.25 mol.s^{-1}. What is the rate of decomposition of potassium chlorate?

A 0.375 mol.s^{-1}
B 0.250 mol.s^{-1}
C 0.167 mol.s^{-1}
D None of the above

QUESTION 2
The curves in the following diagram represent the energy distributions for the same gas sample under two different sets of conditions **A** and **B**.



Which one of the following statements about conditions **A** and **B** is **TRUE?**

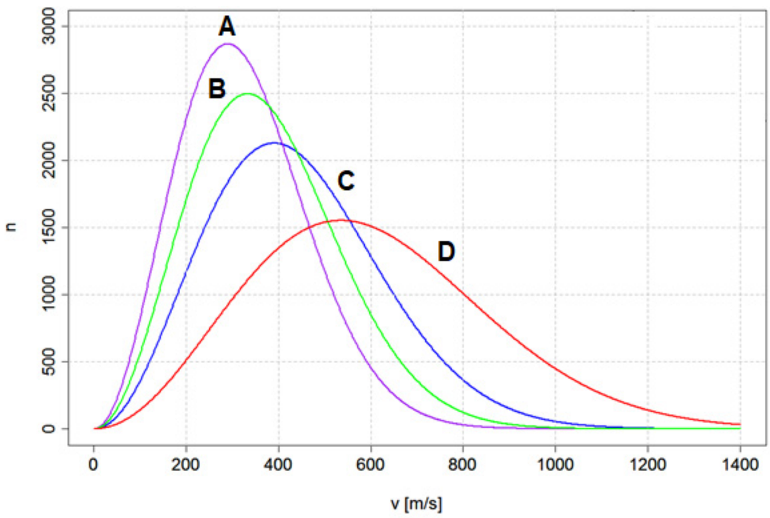
A The average kinetic energy of the molecules under condition **A** is greater than under condition **B**.

B The intermolecular attractive forces are greater for **A** than for **B**.

C The temperature for **B** is greater than for **A**.

D **A** and **B** correspond to the same volumes but the pressure for **A** is greater than the pressure for **B**.

QUESTION 3
The diagram below shows the Maxwell-Boltzman distribution of molecular energies in a sample of gas under different conditions, A, B, C and D.



Which of the following statements is correct?

A The heaviest gas would produce Curve A.
B The lighest gas would produce Curve A.
C The shape of the graph is independent of the molar mass of the gas.
D Curve D represents the energy distribution when a catalyst is added to C.

QUESTION 4
Small temperature rises sometimes causes a large increase in the rate of a chemical reaction because the:

A Average frequency of collisions between particles increases substantially.

B Energy of collisions between particles increases substantially.

C Activation energy for the reaction decreases as the temperature is increased.

D Number of molecules with energy greater than the activation energy increases substantially.

QUESTION 5
Which of the following statements regarding the effect of a catalyst is incorrect?

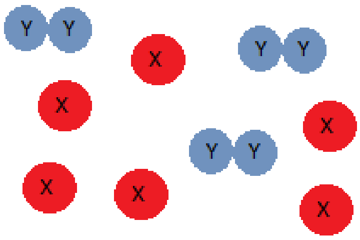
A A catalyst provides an alternative route for the formation of products.
B A catalyst lowers the enregy which molcules need for a successful collision to occur.
C A catalyst provides energy so that more molecules have the minimum energy to react.
D Catalysts form weak bonds with reacting molecules.

QUESTION 6

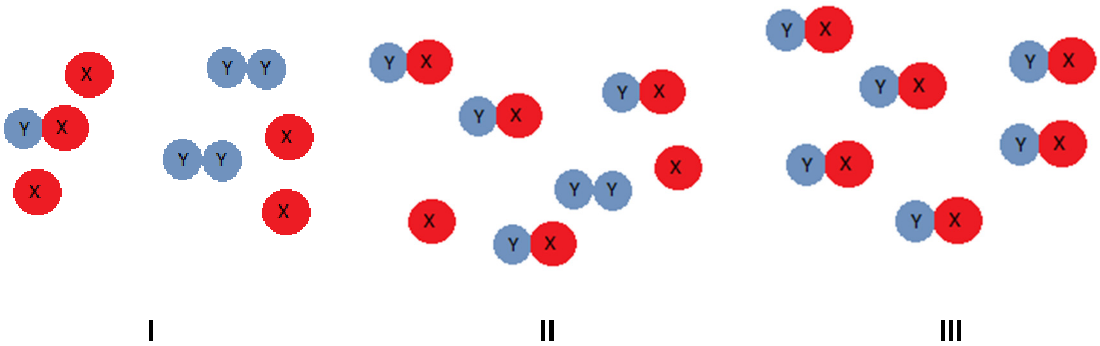
Diagram 1 below shows the initial reaction mixture for the following reaction:

$$2X + Y_2 \rightleftharpoons 2\,XY$$

Diagram 1



Which of the following diagrams shows a possible equilibrium state for this reaction?

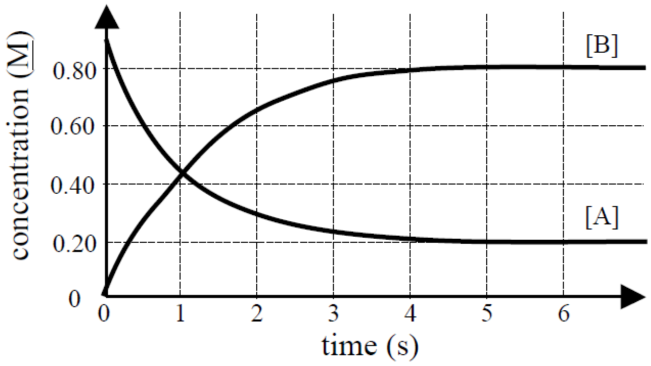


A I
B II
C III
D II & III

QUESTION 7
A sample of A was placed into a reaction vessel and allowed to come to equilibrium according to the following reaction:

$$3A_{(g)} \rightleftharpoons 4B_{(g)}$$

As the system established equilibrium, the following concentration-time graph was produced.



The equlibrium constant for this reaction is closest to

A 0.00031
B 0.020
C 51
D 320

QUESTION 8
Nitryl chloride forms a gaseous equilibrium with nitrogen dioxide and chlorine gas.
This equilibrium may be represented by the following equation:

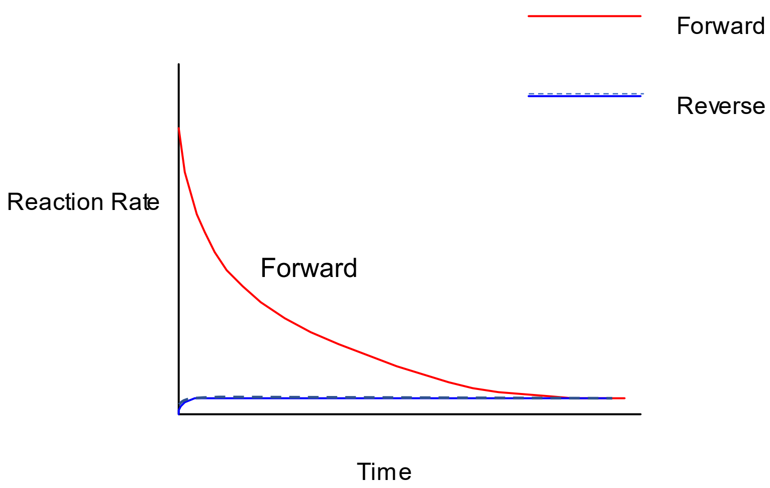
$$2NO_2Cl_{(g)} \rightleftharpoons NO_{2(g)} + Cl_{2(g)} \quad K = 0.558$$

What would be the equilibrium amount (in mol) of NO_2 if the $4.0\,L$ container was found to contain 0.00424 mol of NO_2Cl and 0.02152 mol of Cl_2 at equilibrium?

A 1.17×10^{-4}
B 1.17×10^{-2}
C 4.68×10^{-4}
D 4.68×10^{-2}

QUESTION 9

The following is a rate-time graph for a chemical reaction at constant temperature and volume:



The above reaction:

A Has a high equilibrium constant.
B Has not reached equilibrium.
C Has stopped.
D Has a low equilibrium constant.

QUESTION 10

Carbon monoxide is a by product of the production of hydrogen gas through the reaction of steam and methane. The equation representing the reaction is

$$CH_{4(g)} + H_2O_{(l)} \rightleftharpoons CO_{(g)} + 3H_{2(g)} \quad \Delta H = +206.1\ kJmol^{-1}$$

Which of the following conditions would lead to an increase in the yield of hydrogen gas?

A High temperature and high pressure.
B Low temperature and high pressure.
C High temperature and low pressure.
D Low temperature and low pressure.

QUESTION 11

$$HCN_{(aq)} + H_2O_{(aq)} \rightleftharpoons H_3O^+_{(aq)} + CN^-_{(aq)}$$

Hydrocyanic acid HCN has an equilibrium constant of 6.3×10^{10} for its reaction with water. Which of the following changes would cause the pH and the percent ionisation of a $0.1M$ solution of HCN to increase?

i. Dilution with water
ii. Addition of KCN
iii. Addition of 3 drops H_2O
iv. Addition of $NaOH$

A i
B i & iii
C ii
D i & iv

QUESTION 12

Solid silver chloride is in equilibrium with its aqueous solution at 25^oC.

$$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)} \qquad K = 2.0\times10^{-10}M^2$$

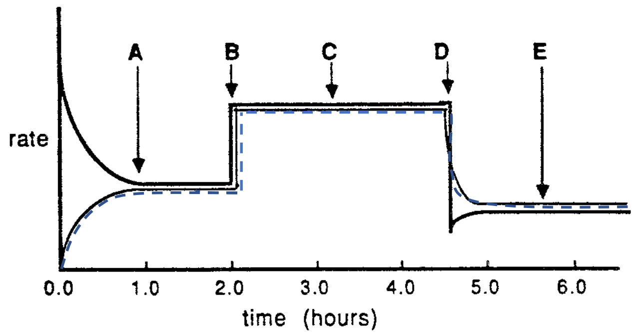
When a solution containing $NH_{3(aq)}$ is added, the solid silver chloride rapidly dissolves.

$$Ag^+_{(aq)} + 2NH_{3(aq)} \rightleftharpoons Ag(NH_3)^+_{2(aq)} \qquad K = 1.6\times10^7 M^{-2}$$

Which of the following actions would result in an **increase** in the amount of undissolved $AgCl_{(s)}$?

A Dilution with water.
B The addition of more ammonia.
C The addition of HCl.
D An increase in the atmospheric pressure.

QUESTION 13
The graph below shows the variation in the reaction rates for the following reactions:



$H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$ $\Delta H = +ve$ (Heavy Line)
$2HI_{(g)} \rightarrow H_{2(g)} + I_{2(g)}$ $\Delta H = -ve$ (Dashed Line)

Which of the following changes was introduced at the 4.5 hour mark?

A A catalyst was added.
B The temperature was increased.
C The temperature was decreased.
D HI was removed.

QUESTION 14
In an electrolysis cell,

A Electrons pass through the electrolyte.

B Positive ions move through the electrolyte towards the electrode at which oxidation occurs.

C Negative ions move through the electrolyte towards the electrode at which oxidation occurs.

D Electrons pass through the salt bridge.

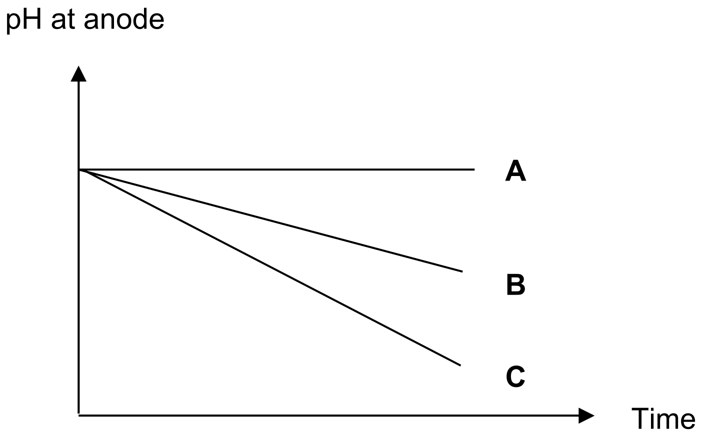
QUESTION 15
In which of the following cells is oxygen gas likely to be produced at the anode?

A The electrolysis of molten potassium iodide using platinum electrodes.
B The electrolysis of aqueous potassium iodide using platinum electrodes.
C The electrolysis of molten sodium chloride using platinum electrodes.
D The electrolysis of aqueous sodium chloride using platinum electrodes.

QUESTION 16
Platinum electrodes were suspended into $500\ mL$ of a solution containing the following ions: $Ag^{+}, Cu^{2+}, Al^{3+}, Ni^{2+}$. If a current is passed through the cell at a constant voltage of $1.40\ V$, the last metal to be deposited onto the cathode would be:

A Ag
B Cu
C Al
D Ni

QUESTION 17
An electrolytic cell was constructed using different concentrations of sodium chloride using platinum electrodes.
The changes in pH that occur at the anode may be represented by curves A, B and C.



Which option below correctly represents the changes in pH that occur at the anode at the different concentrations of $NaCl$?

	$1.0\,M\ NaCl$	$2.5\,M\ NaCl$	$10.0\,M\ NaCl$
A	Curve A	Curve B	Curve C
B	Curve C	Curve B	Curve A
C	Curve A	Curve C	Curve B
D	Curve C	Curve A	Curve B

QUESTION 18

Space travel prompted the development of many technologies including that of small, portable power sources like the rechargeable nickel-hydrogen battery. These batteries contain a basic electrolyte and use hydrogen as the reductant when discharging. One of the reactions that occurs in the battery is

$$NiOOH_{(s)} + H_2O_{(l)} + e^- \rightarrow Ni(OH)_{2(s)} + OH^-_{(aq)}$$

This reaction could describe

A the reaction occurring at the positive electrode when the battery is discharging.
B the reaction occurring at the negative electrode when the battery is recharging.
C the reaction occurring at the positive electrode when the battery is recharging.
D the reaction occurring at the negative electrode when the battery is discharging.

QUESTION 19

In the electrolysis of a 500 ml aqueous solution containing a mixture of the following metal nitrates: $AgNO_3$, $Ca(NO_3)_2$ and $Cr(NO_3)_3$, 289,500 coulombs of charge was supplied to the cell. If the metal nitrates each have a concentration of 1.0 M, what would be the amount, in mole, of each metal deposited at the cathode?

	Ag	**Ca**	**Cr**
A	3.00 mol	0.00 mol	1.00 mol
B	0.50 mol	0.50 mol	0.50 mol
C	0.50 mol	0.00 mol	0.50 mol
D	3.00 mol	2.00 mol	1.00 mol

QUESTION 20

Two inert electrodes were placed in 250 ml of a 1.000 M solution of copper sulfate, $CuSO_{4(aq)}$. An electric current of 4.00 A was passed through the solution and copper was deposited on one of the electrodes. At the end of the experiment the volume was unchanged and the final concentration of copper sulfate was 0.750 M. The time, in minutes, taken for the electrolysis was closest to:

A 25
B 50
C 151
D 201

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided. Write using black or blue pen.

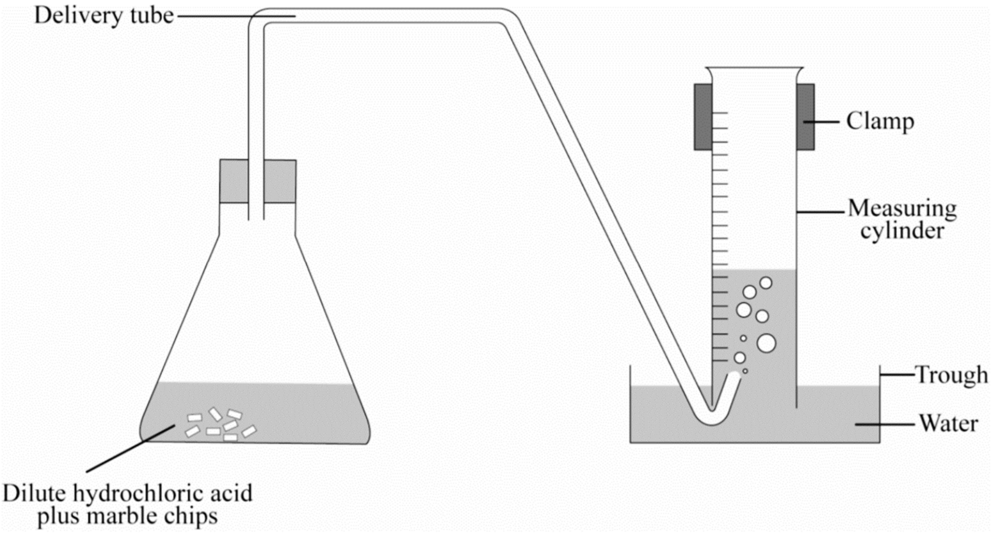
Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.

Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.

Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_{2(g)}$, $NaCl_{(s)}$.

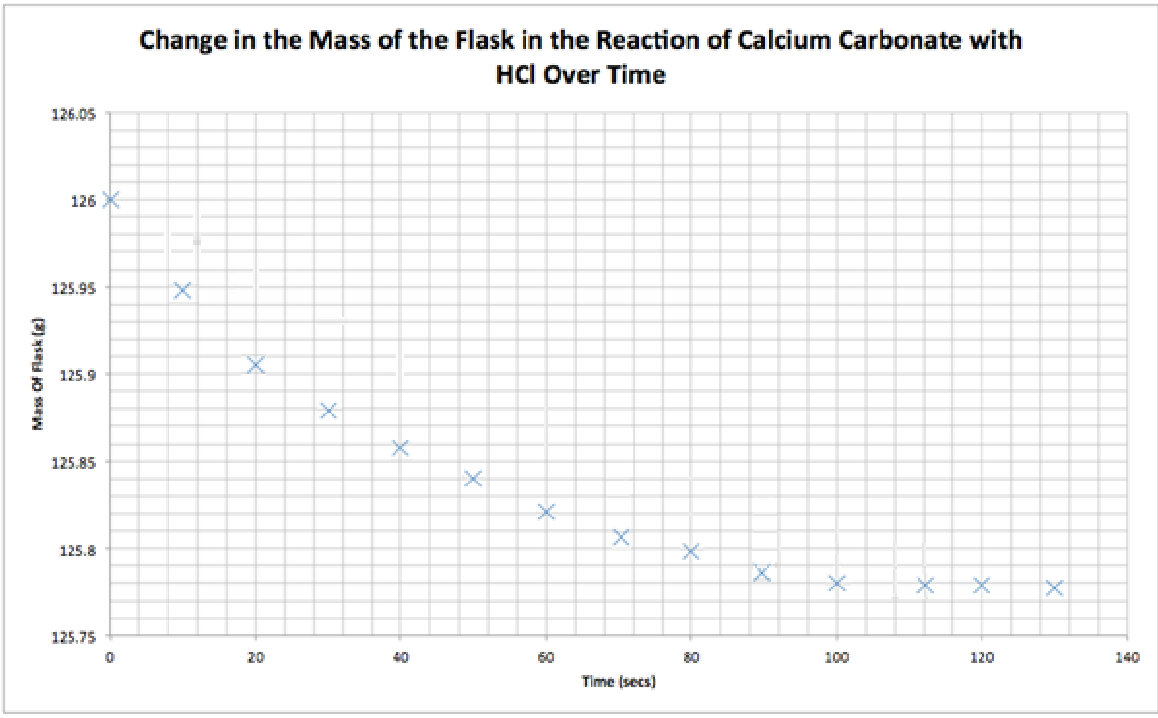
Unless otherwise indicated, the diagrams in this book are not drawn to scale.

QUESTION 1 (11 marks)
Calcium carbonate chips, $CaCO_3$, are reacted with excess hydrochloric acid ($500\ mL$) in a closed flask standing on a balance. The gas produced during the course of the reaction is collected in an inverted measuring cylinder, and the mass of the flask is monitored against time.



$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

The following mass vs time graph was obtained.



a. What three events are required in order for a successful collision to occur?

2 marks

b. **i.** Give a reason why the mass of the vessel doesn't change after 100 seconds.

1 mark

ii. Use the collision theory to explain why the rate of change in mass decreases with time.

2 marks

c. On the given diagram, sketch the graph you would expect to see if the size of the marble chips were larger.

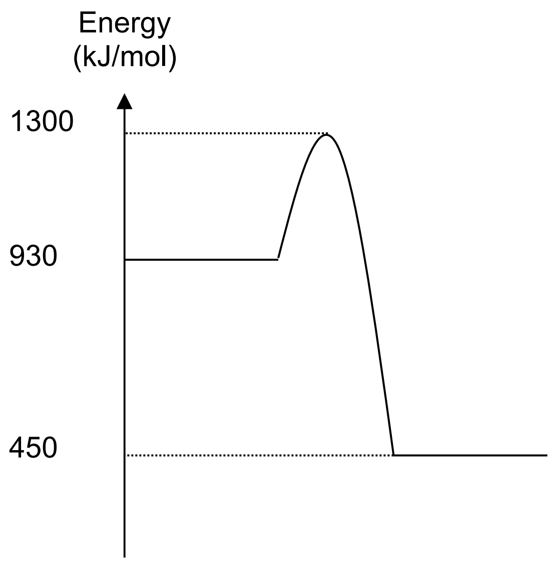
2 marks

d. State four ways (other than surface area) to increase the rate of reaction between the calcium carbonate chips and hydrochloric acid.

4 marks

QUESTION 2 (8 marks)

Below is the energy profile for the reaction: $2A_{(g)} + B_{(g)} \rightarrow C_{(g)}$



a. i. Give the value and sign of the ΔH for the forward reaction.

1 mark

ii. What is the Activation Energy for the back reaction?

1 mark

iii. How would the addition of a catalyst affect the rate of the back reaction?

1 mark

b. **i.** What is the ΔH for the reaction $2C_{(g)} \rightarrow 4A_{(g)} + 2B_{(g)}$?

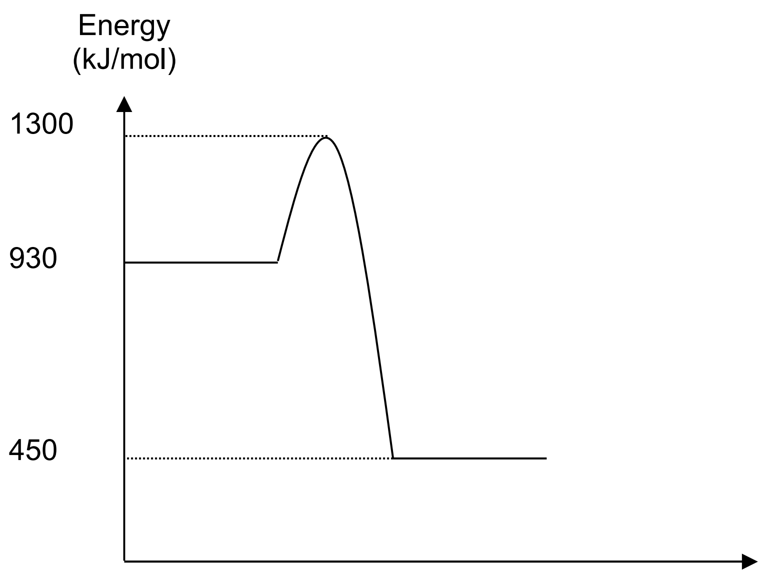
1 mark

ii. Consider the forward reaction. Would you expect the bonds in the reactants to be stronger or weaker than the bonds within the products? Give a reason for your answer.

2 marks

c. On the axes below, sketch the energy changes that would occur for the reaction involving 1.00 mole of A.

$2A_{(g)} + B_{(g)} \rightarrow C_{(g)}$.

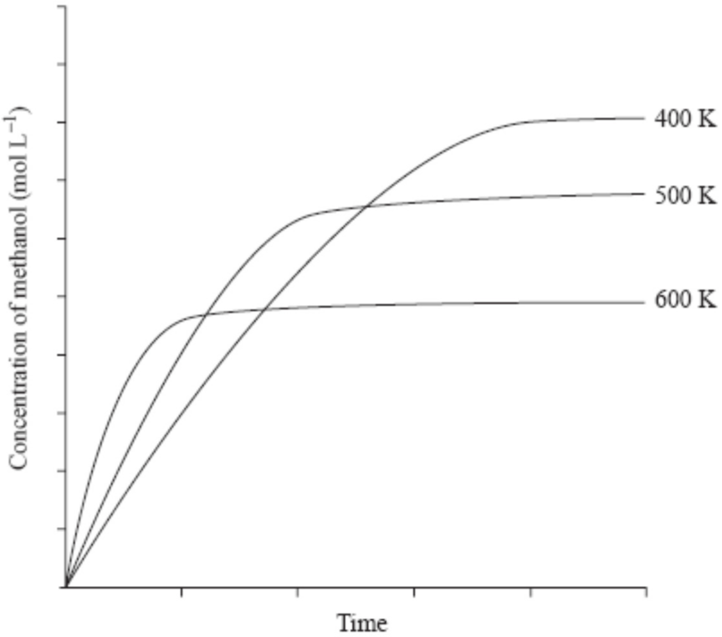


2 marks

QUESTION 3 (11 marks)
Methanol can be prepared industrially according to the following equation:

$$CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$$

The graph below represents the formation of methanol at various temperatures in the absence of a catalyst.



a. Is the formation of methanol endothermic or exothermic? Give a reason for your answer.

____

____

____

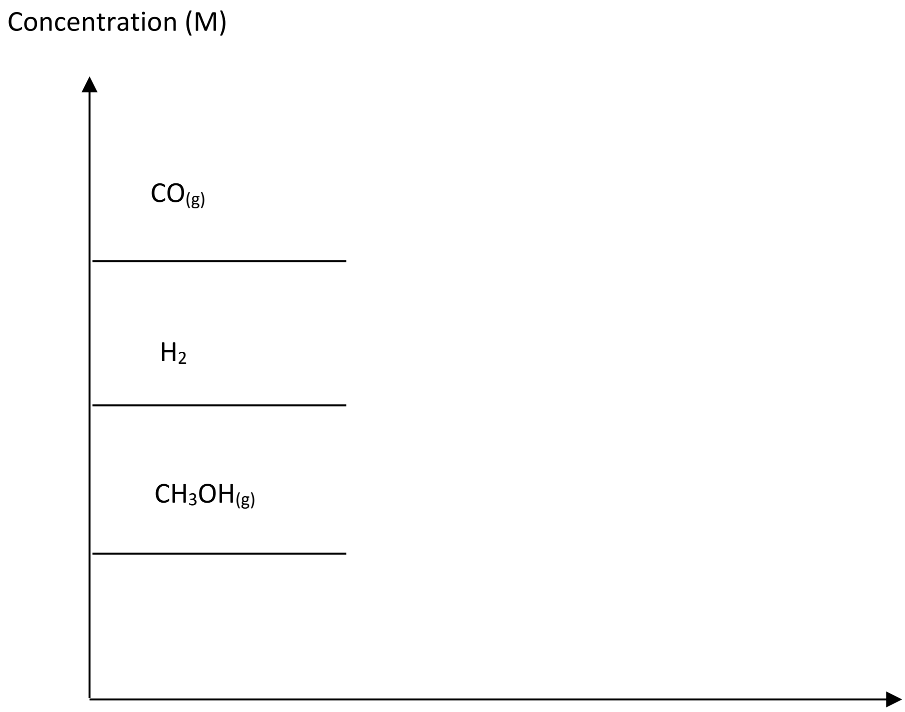
____

2 marks

b. On the graph above, sketch the graph for the formation of methanol at 500 K in the presence of a catalyst.

1 mark

c. Equal amounts of carbon monoxide and hydrogen gas are added to an equilibrium mixture at constant temperature and volume. Sketch the likely changes to the concentration of each gas as the system re-establishes equilibrium.



3 marks

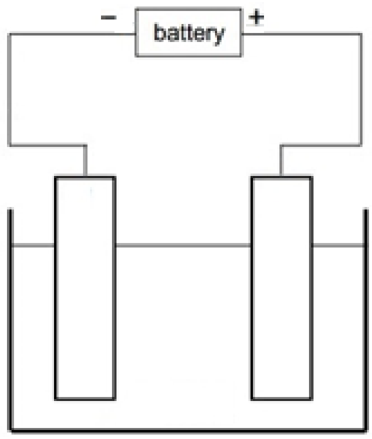
d. 0.40 mole of carbon monoxide gas and 0.50 mole of hydrogen gas are placed in a sealed $2.00\ L$ vessel at constant temperature and allowed to reach equilibrium. At equilibrium, the concentration of hydrogen gas was experimentally determined to be $0.05\ M$. Calculate the equilibrium constant for this reaction.

3 marks

e. At 500 K the numerical value of the equilibrium constant for the reaction is 14·5. How would the value of this equilibrium constant change at 400 K? Explain your answer.

2 marks

QUESTION 4 (8 marks)
A student is setting up an electrolytic cell to electrolyse an acidified $CuCl_2$ solution using silver as the cathode and platinum as the anode.



a. Complete the given diagram labelling the cathode and the anode and the direction of electron flow.

2 marks

b. **i.** State the reaction that will occur at the cathode.

____

1 mark

ii. State the reaction that will occur at the anode.

____

iii. Write an overall equation for the reaction occuring.

____

1 mark

c. **i.** Calculate the emf of the cell.

1 mark

In practice, it is found that a higher potential than calculated must be applied in order for electrolysis to occur.

ii. What is the term used to describe the difference between the actual potential required and the calculated potential?

1 mark

iii. Why is this additional potential required?

1 mark

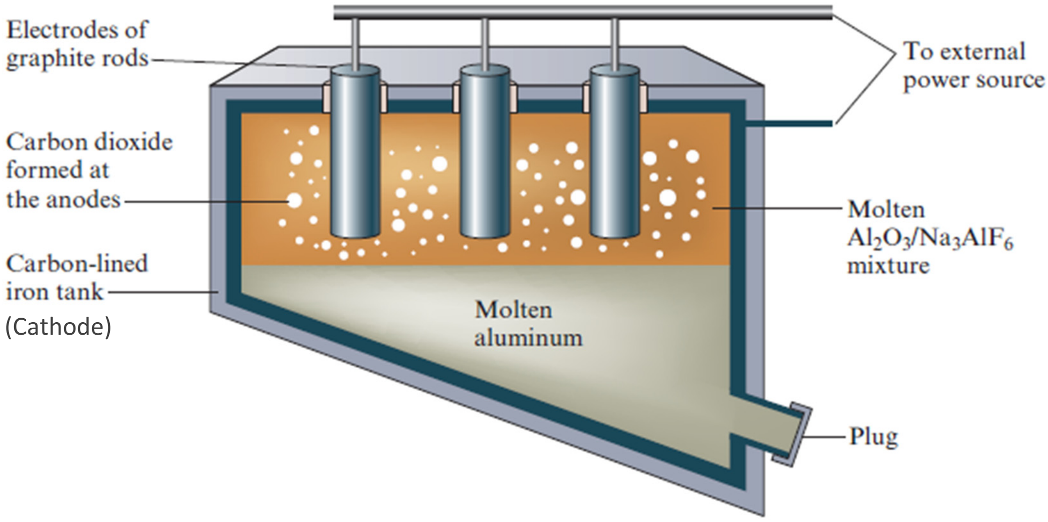
iv. State one reason why care must be taken when deciding on the additional voltage to be supplied to an electrolytic cell.

1 mark

QUESTION 5 (11 marks)
Many important chemicals are produced via electrolytic procedures. Examples of such chemicals include sodium, chlorine, sodium hydroxide and aluminium.

Aluminium is produced on a massive scale every year via the electrolysis of alumina, Al_2O_3. The electrolysis is done in an electrolytic cell called the Hall-Heroult cell, which is shown below.

$$2Al_2O_{3(l)} + 3C_{(s)} \rightarrow 4Al_{(s)} + 3CO_{2(g)}$$



a. **i.** Explain why aqueous solutions of aluminium ions cannot be electrolysed to produce aluminium metal.

___

___

___

1 mark

ii. Why must the anodes be regularly replaced?

___

___

___

1 mark

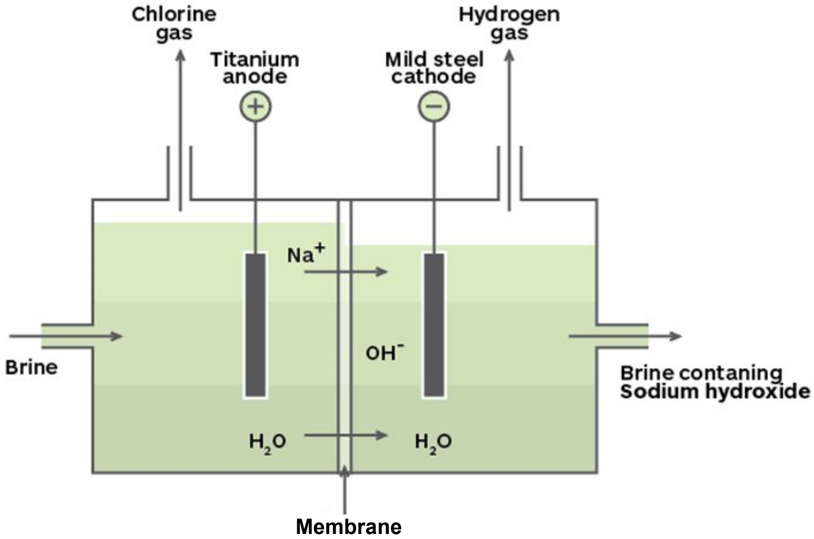
iii. The Hall-Heroult cell operates 24 hours a day using voltages of 5.00 V and a current of 170,000 A. Determine the mass of aluminium produced in this Hall-Heroult cell in one day.

3 marks

iv. How would the mass of aluminium produced be affected if aluminium ions carried a 2+ charge rather than 3+.

1 mark

Chlorine and sodium hydroxide are produced by the electrolysis of concentrated sodium chloride in the Nelson Cell, which is shown below.



b. **i.** Write the half equation for the reactions occuring at the

Positive electrode: ____

Negative electrode: ____

2 marks

ii. Why has a membrane been incorporated into the design of the Nelson Cell?

____

____

____

1 mark

iii. Calculate the volume of chlorine gas that would be produced from $1.00\ L$ of $10.0\ M$ sodium chloride solution. Assume that the gas is collected at a temperature of $298\ K$ and a pressure of $101.3\ kPa$.

____

____

____

____

____

____

2 marks

QUESTION 6 (6 marks)
Each cell of a lead acid car battery consists of two electrodes in aqueous sulfuric acid. The overall reaction that occurs is

$$Pb_{(s)} + PbO_{2(s)} + 2H_2SO_{4(aq)} \rightleftharpoons 2PbSO_{4(s)} + 2H_2O_{(l)}$$

	Electrode X	**Electrode Y**
Made of	Lead	Lead (IV) oxide
Standard Potential	0.36 Volts	1.69 Volts
Product/s Formed When Cell is Discharging	Lead (II) sulfate	Lead (II) sulfate and water

a. Write half equations to show the reactions occurring at the electrodes when the battery is discharging.

Anode: ____

Cathode: ____

2 marks

b. **i.** What is the standard voltage which can be obtained from the above cell?

____

____

1 mark

ii. Each cell of a new commercial car battery actually produces about 2.15 volts. Compare this value with your answer in **b. i** and give a reason for the difference.

____

____

____

____

1 mark

c. Explain why a measurement of the density of the sulfuric acid solution can be used to estimate the extent of discharge of the cell.

1 mark

d. State the reaction that occurs at Electrode Y when the cell is being recharged.

1 mark

TSFX TRIAL EXAMINATION PAPER 2023

VCE CHEMISTRY UNIT 3

AREA OF STUDY 2

DETAILED ANSWERS

Errors and updates relating to this examination paper will be posted at
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SECTION A – MULTIPLE-CHOICE QUESTIONS

QUESTION 1	Answer is A	**QUESTION 11**	Answer is B
QUESTION 2	Answer is B	**QUESTION 12**	Answer is B
QUESTION 3	Answer is C	**QUESTION 13**	Answer is D
QUESTION 4	Answer is D	**QUESTION 14**	Answer is B
QUESTION 5	Answer is A	**QUESTION 15**	Answer is C
QUESTION 6	Answer is B	**QUESTION 16**	Answer is A
QUESTION 7	Answer is C	**QUESTION 17**	Answer is B
QUESTION 8	Answer is B	**QUESTION 18**	Answer is C
QUESTION 9	Answer is B	**QUESTION 19**	Answer is D
QUESTION 10	Answer is C	**QUESTION 20**	Answer is A

QUESTION 1 Answer is C

Rate of decomposition $= 2/3\ rate\ of\ \ oxygen\ formation = \frac{2}{3} \times 0.25 = 0.167\ mol.s^{-1}$

The term 'decomposition' means that the rate will be a positive number.

QUESTION 2 Answer is C

The average kinetic energy occurs to the right of the maximum points on the curves. Reading values off the horizontal axis, the average speed of A is lower than B.

The Maxwell-Boltzman curve does not provide any information regarding the strength of interparticle forces, therefore, the answer cannot be B.

Option C is correct as at the higher temperature, a greater proportioon of molecules has the minimum energy to react, as reflected by the area under the curve from a specific speed.

Increasing pressure keeping volume constant would increase the temperature. As the temperature of B is higher, it must have the higher pressure, not A.

QUESTION 3 Answer is A

The heavier the particle, the slower it will travel.

QUESTION 4 Answer is D

QUESTION 5 Answer is C

QUESTION 6 Answer is B

Initial reaction mixture $2X + Y_2 \rightleftharpoons 2XY$

Diagram 1 is not a possible equilibrium state.

2 particles of X have reacted which means that 1 particle of Y_2 should also react to give 2 particles of XY. In diagram I, there is only 1 particles of XY.

Diagram 2 is a possible equilibrium state. 4 particles of X have reacted with 2 particles of Y_2 to give 4 particles of XY, which is predicted by the mole ratio of the equation.

Diagram 3 is not a possible equilibrium state.

For a reaction at equilibrium, all reactants and products are present to some extent.

QUESTION 7 Answer is C

$$K = \frac{[B]^4}{[A]^3} = \frac{(0.8)^4}{(0.2)^3} = 51.2$$

QUESTION 8 Answer is C

$$K = \frac{[NO_2][Cl_2]}{[NO_2Cl]^2} = 0.558$$

$$[NO_2] = \frac{0.558 \times [NO_2Cl]^2}{[Cl_2]}$$

$$[NO_2] = \frac{0.558 \times \left[\frac{0.00424}{4.0}\right]^2}{\left[\frac{0.02152}{4.0}\right]} = 1.17 \times 10^{-4}\,M$$

$$n(NO_2) = cV = 1.17 \times 10^{-4} \times 4.0 = 4.68 \times 10^{-4}\,mol$$

QUESTION 9 Answer is A

The graph shows that the forward reaction occurs to a great extent, and that the back reaction occurs to a small extent. This would occur if the equilibrium constant favoured the formation of products i.e. its value was high.

QUESTION 10 Answer is C

The reaction is endothermic, hence an increase in temperature would favour a forward reaction, thus producing more hydrogen. As there are more gaseous particles on the right, the forward reaction would be favoured by a decrease in pressure. An increased yield of hydrogen gas would come from high temperatures and low pressures.

QUESTION 11 Answer is D

i. and iv are correct

i. Dilution with water

If the solution is diluted, then the concentration of all reactants and products will decrease and will not return to their initial concentrations once equilibrium is re-established. Since the $[H_3O^+]$ has decreased, the pH will increase. Water is a reactant so the dilution would push the equilibrium to the right and there would be an increase in the % ionisation of the acid.

ii. Addition of KCN

The addition of KCN would add CN^- ions to the system. This would push the equilibrium to the left and reduce the % ionisation. The $[H_3O^+]$ would go down so the pH would increase.

iii. Addition of 3 drops of water.

The addition of 3 drops of H_2O would push the reaction to the right so that the % ionisation increases and the $[H_3O^+]$ would increase which would decrease the pH.

iv. Addition of NaOH.

The $NaOH$ would react with the H_3O^+ pushing the equilibrium to the right to partially oppose the removal of the H_3O^+. Therefore the % ionisation would increase. The amount of H_3O^+ will also increase while equilibrium is being re-established, but because the net forward reaction only *partially* opposes the loss of H_3O^+, the $[H_3O^+]$ will not return to its original concentration. Therefore, at the new equilibrium the $[H_3O^+]$ will be less than before and the pH will have increased.

QUESTION 12 Answer is A

We are concerned with actions that result in a net back reaction. When a dilution occurs, the system will respond by favouring the reaction that will produce the greater number of particles. A net back reaction therefore occurs in the second equation. The increase in Ag^+ will trigger a net back reaction in the first equation and hence the amount of undissolved $AgCl_{(s)}$ will increase.

QUESTION 13 Answer is C

If a catalyst was added to the system then both the forward and reverse reactions would increase.

As the reverse reaction is occuring to a greater extent than the forward reaction, a net back reaction is occuring. If product was removed then a net forward reaction would occur. The answer cannot therefore be D.

A increase in temperature will favour the reaction that will decrease the temperature. As the forward reaction is endothermic, a net forward reaction occurs.

A decrease in temperature will favour the reaction that will increase the temperature. As the forward reaction is endothermic, a net back reaction occurs. The answer is C.

QUESTION 14 Answer is C

Oxidation occurs at the anode, which is signed positive in electrolytic cells.
Negative ions will therefore migrate towards the anode.

QUESTION 15 Answer is D

The production of oxygen gas at the anode is a result of the oxidation of H_2O. Hence, no oxygen gas will be formed from molten substances. Iodide, I^-, is a stronger reductant than H_2O and would be preferentially oxidised at the cathode in aqueous potassium iodide. However, in aqueous sodium chloride, the H_2O is a stronger oxidant than the chloride, Cl^-, so oxygen gas would be produced.

QUESTION 16 Answer is B

To deposit Ni, an EMF of 1.46 V is required – which is more than the voltage being supplied. As Al^{3+} is a weaker oxidant than water, water will react at the cathode, and hence Al will not be produced. The last metal to be deposited is therefore Cu.

QUESTION 17 Answer is B

Under standard conditions (1 M) the following reactions will occur:

$$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$$

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$$

Therefore, the pH at the cathode increases and the pH at the anode decreases.

At very high concentrations (10 M), the following reactions occur:

$$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(aq)}$$

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$$

Therefore, the pH at the cathode increases and the pH at the anode stays relatively constant.

At intermediate concentrations (2.5 M NaCl), both possible anode reactions occur.

$$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(aq)}$$

$$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$$

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$$

Therefore, the pH at the cathode increases and the pH at the anode decreases, but to a smaller extent than that observed with $1M\ NaCl$.

QUESTION 18 Answer is **A**

The given information tells us that hydrogen is the reductant when the cell is discharging. From that we can determine the following:

Discharging	Recharging
Hydrogen is the reductant.	Nickel ions are the reductant.
Nickel ions are the oxidant.	Hydrogen is the oxidant.

The equation $NiOOH_{(s)} + H_2O_{(l)} + e^- \rightarrow Ni(OH)_{2(s)} + OH^-_{(aq)}$ shows a nickel compound acting as an oxidant and being reduced in the process. Therefore, this reaction is occurring as the cell is discharging and would be occurring at the cathode which is +ve in a galvanic system.

QUESTION 19 Answer is C

As electrons are present in excess, the mole of metal produced depends on the mole of metal ions. Ca^{2+} is a weaker oxidant than H_2O and hence will not be reduced at the cathode. No calcium metal would be deposited.

QUESTION 20 Answer is B

$$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$$

$$n(Cu^{2+})_{used} = cV = 0.250 \times 0.250 = 0.0625\ mol$$
$$n(e^-) = 2 \times n(Cu^{2+})_{used} = 2 \times 0.0625 = 0.125\ mol$$

$$Q = n(e^-) \times F = 0.125 \times 96,500 = 12,062.5$$

$$Q = It$$

$$\therefore t = \frac{Q}{I} = \frac{12,062.5}{4.00} = 3,015.6\ sec = 50.26\ min$$

SECTION B

QUESTION 1

a. Particles collide.
They collide with sufficient force to overcome the activation energy barrier.
They collide in the correct orientation.

1 mark is awarded for 1 of the events.
2 marks are awarded for all 3 of the events.

b. **i.** As all the calcium carbonate has reacted.*

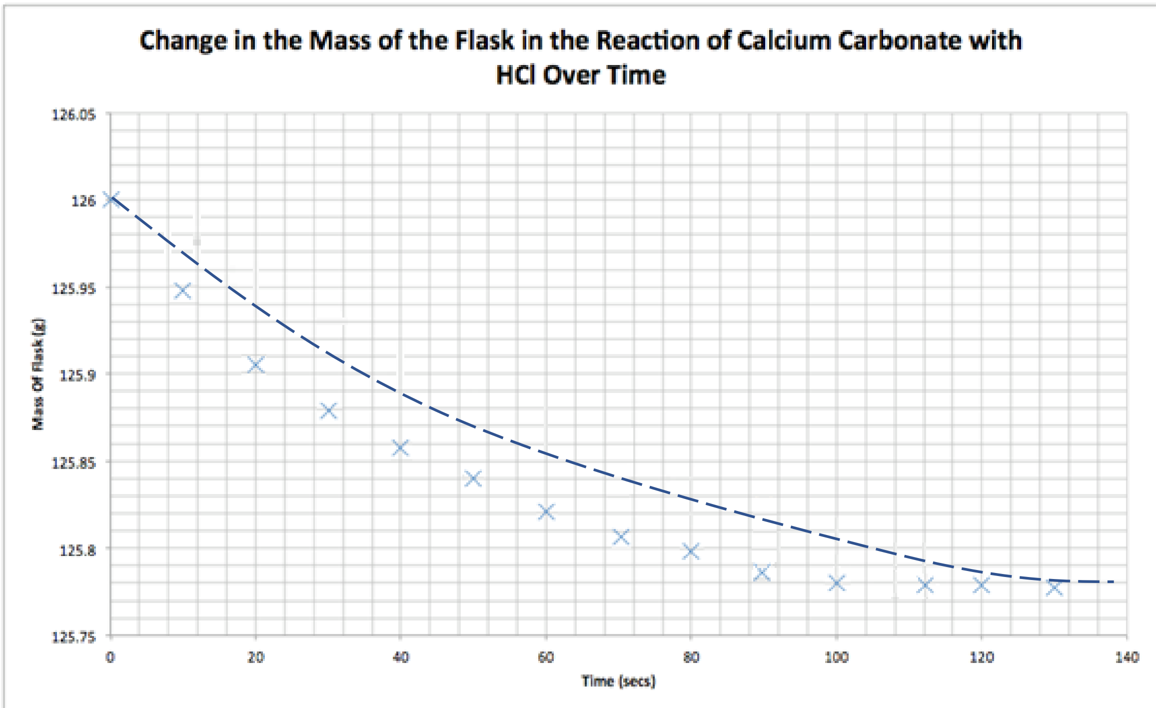
ii. As the reaction proceeds, the reaction rate decreases due to a decrease in concentration of acid particles.*

As the concentration of acid decreases, fewer of the reacting particles come into contact with one other. This results in less frequent collisions, a lower probability of a successful collision occurring, and hence the reaction rate decreases.*

c. As the total mass of marble chips are the same, the initial mass is the same as that for the smaller chips.

As the reaction rate would be slower, it will take longer for the reaction to stop.

The gradient of the curve would be smaller across its entire length.



d. Any four of the following:

Increase the volume of acid.
Increase the concentration of acid.
Increase the temperature.
Add a catalyst.
Stir the solution.

QUESTION 2

a. **i.** $\Delta H = H_{final} - H_{initial} = 450 - 930 = -480\ kJ/mol$

ii. $\Delta H = H_{final} - H_{initial} = 1300 - 450 = 850\ kJ/mol$

iii. Catalysts affect the rate of the back reaction to the same extent as the forward reaction. i.e. the back reaction rate would increase.

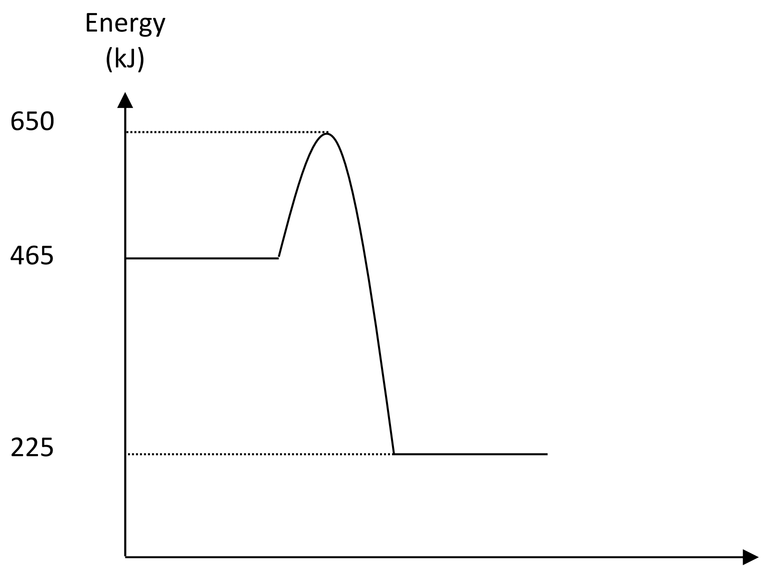
b. **i.** Reverse and double that of the forward reaction.

$-2(-480\ kJ/mol) = 960\ kJ/mol$

ii. The bonds in the products are stronger as it takes more energy to convert the products to the activated complex than it does to convert the reactants to the activated complex.

c. Halve every marked quantity.

1 mark is awarded for halving each enthalpy.
1 mark is awarded for the correct shape.

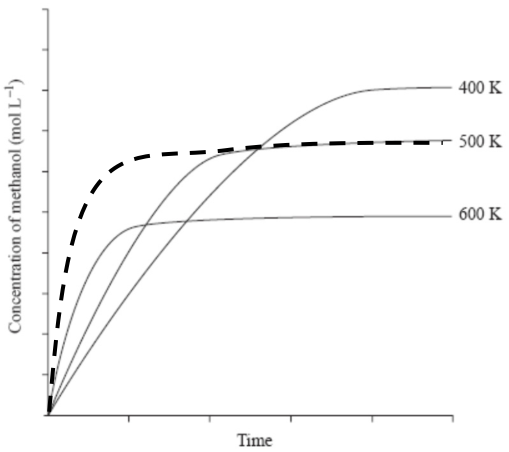


QUESTION 3

a. As the temperature increases, the yield of methanol decreases i.e. a net back reaction is occurring.* This would occur in response to increasing the temperature of a system whose forward reaction is exothermic.*

b. A catalyst will enable the system to reach the maximum yield in a shorter time frame – but it will not change the final yield. The curve must therefore start and end at the same concentrations, but the maximum concentration is reached sooner.*

As catalysts increase reaction rates, the curve needs to be steeper.



c. Mole ratios must be observed.

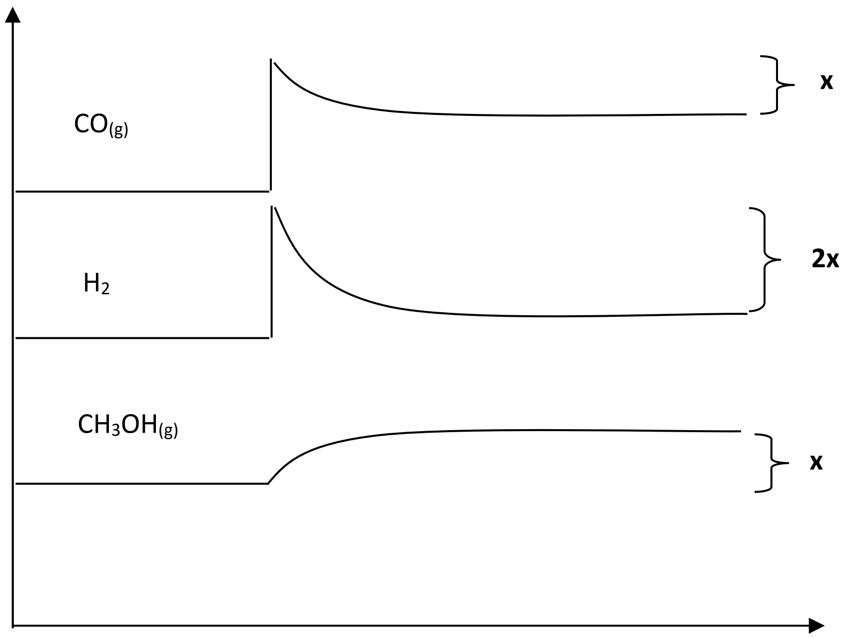
Equal amounts of both gases are added at constant volume i.e. concentration change is the same upon addition.

When the two reactants are added to the equilibrium mixture, a net forward reaction occurs. The reactant concentrations will gradually decrease but will never return to their previous values. As the reaction proceeds via a net forward reaction, the concentration of product gradually increases and then reaches a steady value.

Note: The concentration of $H_{2(g)}$ will change twice as much as the other gases (see mole ratios in the balanced equation).

1 mark is awarded for correctly drawing the changes in CO concentration.
1 mark is awarded for correctly drawing the changes in H_2 concentration.
1 mark is awarded for correctly drawing the changes in CH_3OH concentration.

Concentration (M)



d. $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$

	$CO_{(g)}$	$H_{2(g)}$	$CH_3OH_{(g)}$
Initial Mole	**0.40**	**0.50**	0
Mole Ratio For Reaction	1	2	1
Mole Transferred	$\frac{0.40}{2} = 0.20 \downarrow$	$0.50 - 0.10 = 0.40 \downarrow$	$0.20 \uparrow$
Mole at K [1 mark]	$0.40 - 0.20 = 0.20$	**n=cV=0.05×2=0.10**	$0 + 0.20 = 0.20$
Concentration at Equilibrium	$C = \frac{0.20}{2} = 0.10M$	$C = 0.05\ M$	$C = \frac{0.20}{2} = 0.10M$

$$K = \frac{[CH_3OH_{(g)}]}{[CO_{(g)}][H_{2(g)}]^2}\ M^{-2}\ *$$

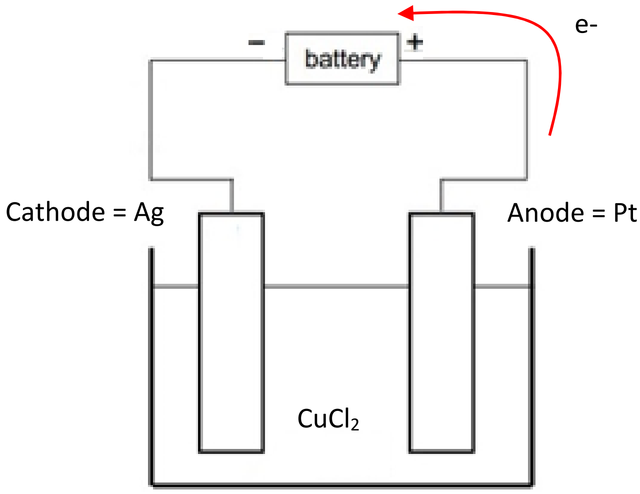
$$K = \frac{(0.10)}{(0.10)(0.05)^2}\ M^{-2} = 400\ M^{-2} = 4.0 \times 10^2\ M^{-2}\ **$$

1 mark is awarded for the correct equilibrium expression.
1 mark is awarded for 1 correct concentration.
1 mark is awarded for the correct answer and unit.

e. As the forward reaction is exothermic, lowering the temperature would favour a net back reaction so that the temperature can be decreased.* The concentration of product decreases and the concentration of reactants increases and hence the value of K decreases.*

QUESTION 4

a.



1 mark is awarded for labelling the cathode or anode.
1 mark is awarded for labelling the electron flow.

b. **i.** $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$ *

ii. $2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$ *

Never consider the cathode material as one of the potential reactants. As long as the cathode is an electrical conductor, the material it is made from is irrelevant.

iii.

$$2Cu^{2+}_{(aq)} + 4e^- \rightarrow 2Cu_{(s)}$$
$$2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$$

$$2Cu^{2+}_{(aq)} + 2H_2O_{(l)} \rightarrow 2Cu_{(s)} + O_{2(g)} + 4H^+_{(aq)}$$ *

c. **i.** $EMF = E^o_{Cathode} - E^o_{Anode} = 0.34 - 1.23 = -0.89\ V$ *

ii. Overpotential

iii. To compensate for the nature of the electrodes, temperature, current density, resistance etc.

iv. If too much additional voltage is provided, other reactions could occur.

QUESTION 5

a. **i.** If the solution was aqueous, water would be reduced instead of aluminium since water is a stronger oxidant than aluminium ions.

ii. The anodes take part in the reaction and waste away. Therefore, they need to be replaced on a regular basis.

iii. $Q = I \times t$

$= 170000 \times 24 \times 60 \times 60$

$= 1.47 \times 10^{10} C*$

$$n(e^-) = \frac{1.47 \times 10^{10}}{96500} = 1.52 \times 10^5 mol$$

$$n(Al) = \frac{1}{3} \times n(e^-) = \frac{1.52 \times 10^5}{3} = 5.07 \times 10^4 mol*$$

$$m(Al) = 5.07 \times 10^4 \times 27 = 1.37 \times 10^6 g = 1.37 \times 10^3 kg*$$

iv. If the charge on the aluminium was +2 rather than +3, fewer electrons would be needed per mole to convert aluminium ions into aluminium metal. The excess electrons would then be used to produce more Al.

b. **i.** Positive electrode: $2Cl^-_{(aq)} \rightarrow Cl_{2\ (g)} + 2e^-$

Negative electrode: $2H_2O_{(l)} + 2e^- \rightarrow H_{2\ (g)} + 2OH^-_{(aq)}$

ii. This membrane ensures that the products do not mix and recombine to form reactants once they have been produced at the electrodes.

iii. $2Cl^-_{(aq)} \rightarrow Cl_{2\ (g)} + 2e^-$

$$n(NaCl) = n(Cl^-) = cV = 1.00 \times 10.0 = 10.0\ mol$$

$$n(Cl_2) = \frac{1}{2} \times n(Cl^-) = \frac{1}{2} \times 10.0 = 5.00\ mol\ *$$

$$n(Cl_2) = \frac{V}{24.5}$$

$$\therefore V = 5.00 \times 24.5 = 122.5 = 122\ L\ *$$

QUESTION 6

a. X = Anode: $Pb_{(s)} + SO_{4(aq)}^{2-} \rightarrow PbSO_{4(s)} + 2e^-$

Y = Cathode: $PbO_{2(s)} + 4H_{(aq)}^{+} + SO_{4(aq)}^{2-} + 2e^- \rightarrow PbSO_{4(s)} + 2H_2O_{(l)}$

b. **i.** $EMF = E_{reduction}^{o} + E_{oxidation}^{o} = 1.69 + 0.36 = 2.05\,V$

$PbO_{2(s)} + 4H_{(aq)}^{+} + SO_{4(aq)}^{2-} + 2e^- \rightarrow PbSO_{4(s)} + 2H_2O_{(l)} \quad E^o = 1.69\,V$

$PbSO_{4(s)} + 2e^- \rightarrow Pb_{(s)} + SO_{4(aq)}^{2-} \quad E^o = -0.36\,V$

ii. The calculated EMF is based on reactions occuring under standard conditions. As the concentration of sulfuric acid used is much greater than one molar, deviations in E^o values will occur.

c. As the cell discharges, the concentration of sulfuric acid decreases and as the concentration of sulfuric acid decreases, the density decreases.

d. $PbSO_{4(s)} + 2e^- \rightarrow Pb_{(s)} + SO_{4(aq)}^{2-}$