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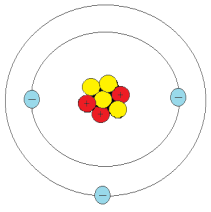
Pure Chemistry Intensive: Inorganic Chemistry

Important Keywords:

Keyword(s)	Definition
Elements	Simplest form of substance that cannot be further broken down by chemical methods.
Compounds	Substances that are formed by two or more elements chemically combined.
Mixture	Substances that are physically mixed together.
Atoms	The smallest particle of an element.
Molecules	Formed when two elements are chemically combined.
*Isotopes	Atoms with same number of _____ and different number of _____
Ions	Formed when atoms gain or lose electron(s)
Relative Atomic Mass (A_r)	_____ mass of an _____ compared to _____
Relative Molecular Mass (M_r)	_____ mass of an _____ compared to _____
Nucleon Number	Total number of neutrons and protons in an atom.
Valence Electrons	Electrons of atoms (or ions) at outermost shell.
Metallic Character	Refers to the tendency to lose electrons to form positively charged cations.

Subatomic Particles

	Relative Mass	Relative Charge
Protons		
	1	0
Electrons		



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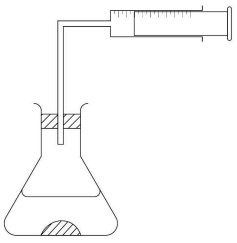
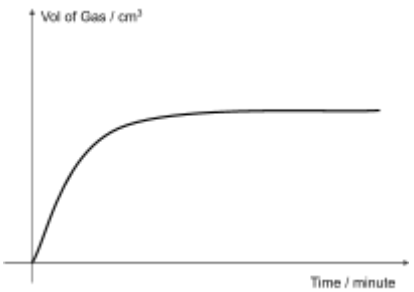
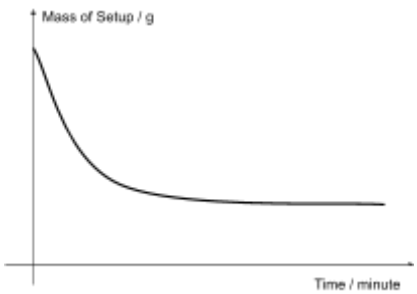
Rate of Reaction

How to increase rate of reaction

Temperature 1. Temperature _____ 2. Kinetic energy of particles _____	
Concentration of solution 1. Concentration _____ 2. Amount of reactants per unit volume _____	
Size of Particles (Solid Reactant) 1. Size of particles _____ (powder form) 2. Surface area available for reaction _____	
Pressure of Gaseous Reactants 1. Pressure _____ 2. Gaseous Reactants are closer together	
Catalyst 1. Presence of catalyst 2. Activation energy of reaction is lowered 3. More reactants achieve activation energy 4. Rate of reaction increases	

	Gas Collection Graph	Change of Mass Graph
Set-up		
General Understanding		

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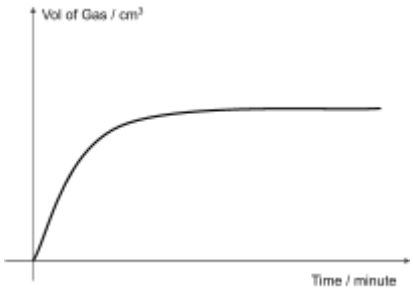
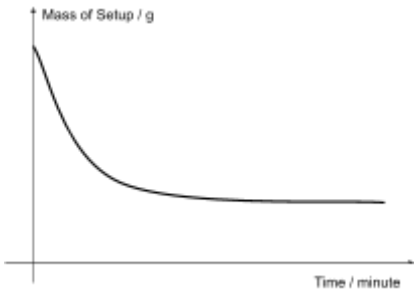
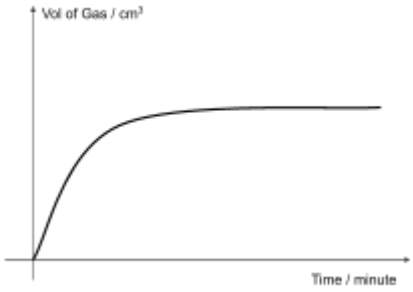
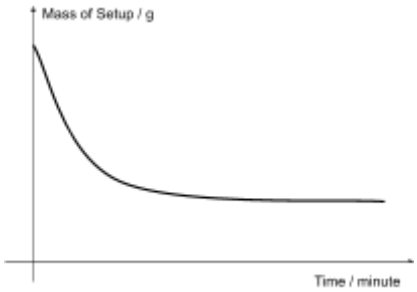
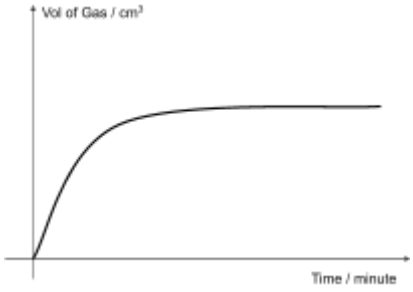
Graphical Effects of Factors on Speed of Reaction

Factors	Gas Collection Graph	Change of Mass Graph
Higher Temperature OR Smaller Solid Reactants		
Double Concentration Solution is limiting		
Double Volume Solution is limiting		

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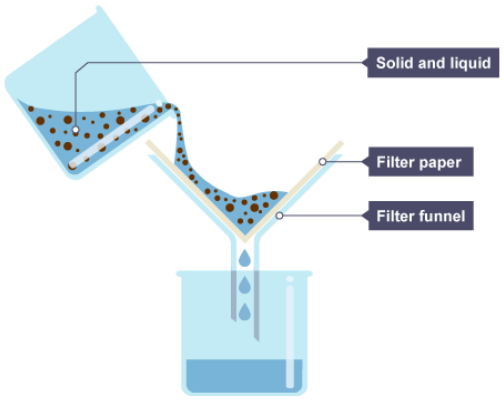
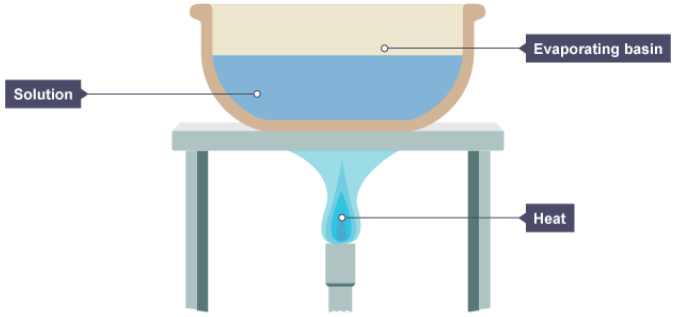
Purification Techniques

Filtration



Evaporation to dryness



Crystallisation

1. _____ till saturated
2. _____ the saturated solution
3. _____ the crystals
4. Blot _____

Sublimation

Chromatography

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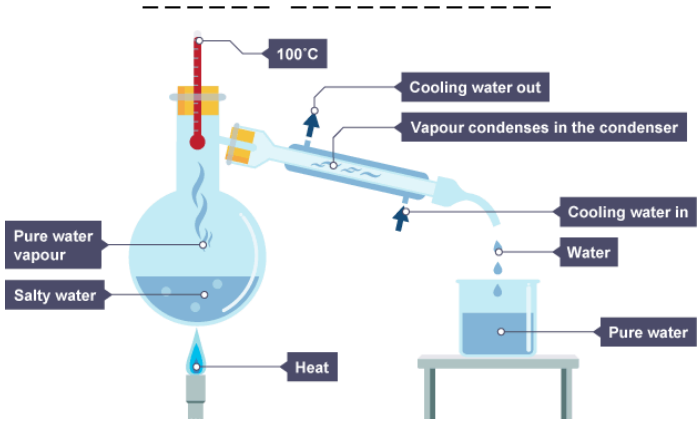

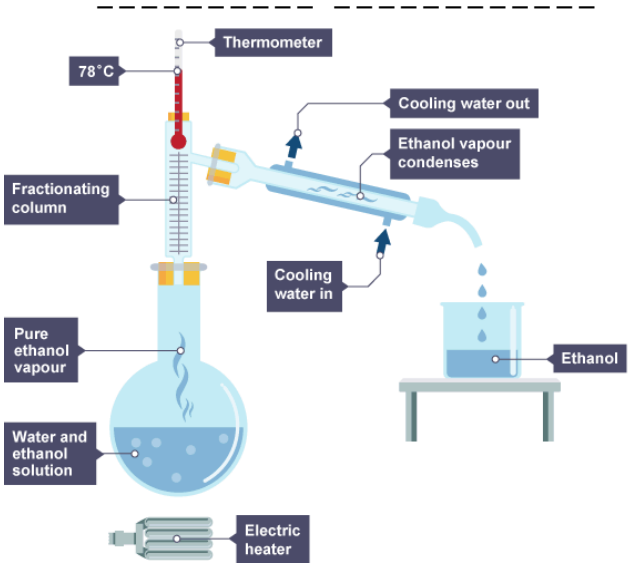

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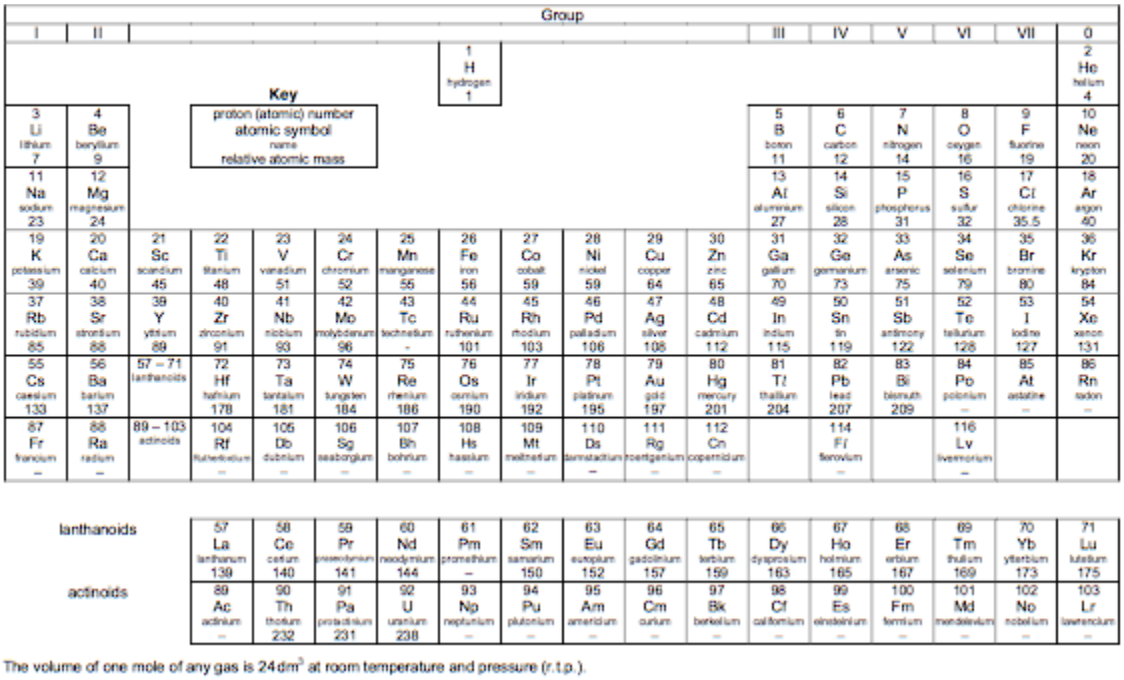
Periodic Table

- Elements are arranged based on _____ number
- Group represents the number of _____ electrons
- Period represents the number of _____ shells



Group	I	II											III	IV	V	VI	VII	0
							1 H hydrogen 1											2 He helium 4
	3 Li lithium 7	4 Be beryllium 9		Key: proton (atomic) number; atomic symbol; name; relative atomic mass									5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
	11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
4	19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
5	37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium -	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
6	55 Cs caesium 133	56 Ba barium 137	57 – 71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
7	87 Fr francium –	88 Ra radium –	89 – 103 actinoids	104 Rf Rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

	Group I (_ _ _ _ _ _ metals)	**Transition Metals**	**Group VII (_ _ _ _ _ _ _)**	**Group 0 (_ _ _ _ _ Gases)**
Properties	- Soft - Low Density - Other metallic properties	- Forms _ _ _ _ _ _ _ _ compounds - Have _ _ _ _ _ _ _ _ oxidation states - Used as _ _ _ _ _ _ _ _	- - Forms covalent substances	- -
Trends	- Density - Reactivity - Melting/Boiling point		- Density - Reactivity - Melting/Boiling point - Colour	

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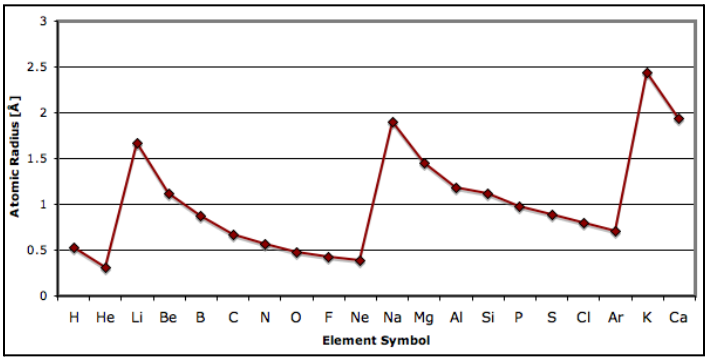
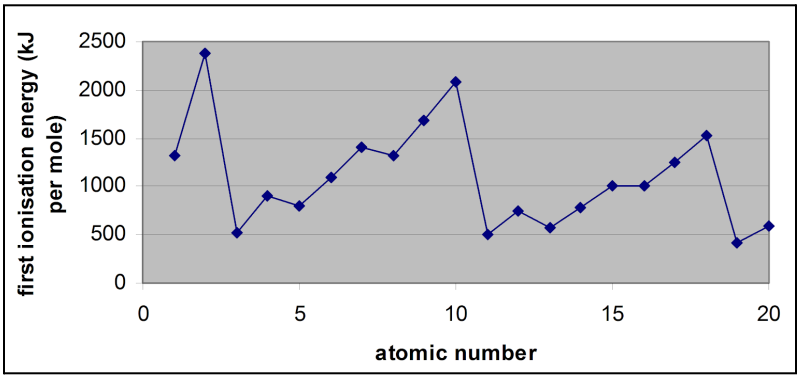
Other Important Ideas:

Terms	Definitions/ Ideas
Nuclear Attraction	Forces of attraction between _ _ _ _ _ _ _ (in the nucleus) and _ _ _ _ _ _ _ _ _.
Electron Shielding	Forces of repulsion between _ _ _ _ _ _ _ _ _ between _ _ _ _ _ _ _ _ _ _ shells.
Atomic Radius	Distance from the centre of atom to valence electron of atom 
Ionic Radius	Distance from centre of ion to valence electron of ion
Ionisation Energy	Energy required to lose 1 electron to form a positively charged ion. 

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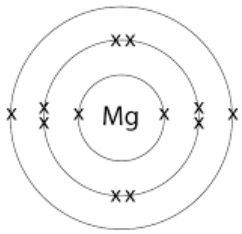
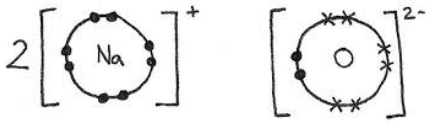
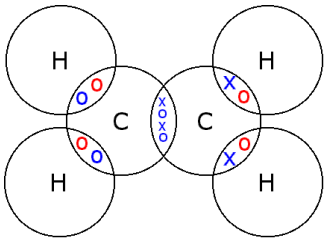
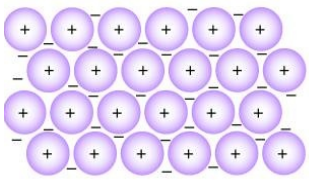
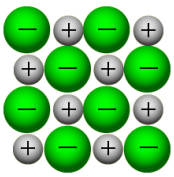
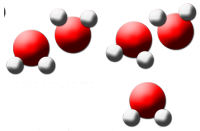
Physical & Chemical Bonding

Metallic	Ionic	Simple Covalent
		
		
Lattice structure Metal atoms surrounded by mobile electrons	Crystal lattice structure. _____ and _____ ions are alternately positioned	Molecules are irregularly arranged, far apart from each other.
High melting & boiling point Strong metallic forces of attraction require a large amount of energy to overcome. Conduct electricity in solid state Have mobile _____	High melting & boiling point Strong _ _ _ _ _ _ _ _ _ _ _ _ _ _ forces of attraction requires _____ amount of energy to overcome. Does not conduct electricity in solid Conducts electricity in liquid & aqueous state	Low melting & boiling point _____ _____ forces of attraction requires _____ amount of energy to overcome. Does not conduct electricity Exceptions:

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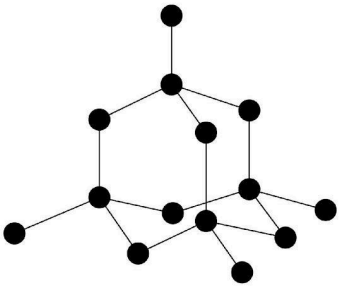
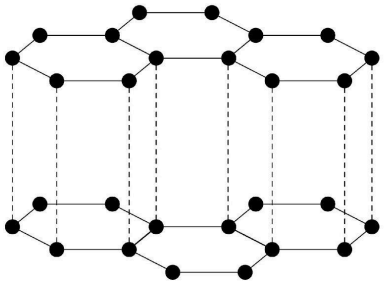
Allotropes of Carbon (Macromolecules)

Diamond	Graphite
	
Structure: 1. _____ structure 2. Each carbon atom bonded to _____ carbon atoms 3. Strong covalent bonds between atoms	Structure: 1. _____ layers 2. Each carbon bonded to _____ carbon atoms 3. Strong covalent bonds between atoms 4. Weak intermolecular forces of attraction between hexagonal layers
Physical Properties: 1. High melting & boiling point Strong _____ _____ between atoms require large amount of energy to overcome. 2. Does not conduct electricity Does not have mobile _____. 3. Hard When a force is applied, atoms are unable to slide across neighbouring atoms due to _____	Physical Properties: 1. High melting & boiling point Strong _____ _____ between atoms require large amount of energy to overcome. 2. Conducts electricity Have mobile _____ between _____. 3. Soft & slippery When a force is applied, _____ slide across each other due to _____
Use as tips for drills	Use to lubricate machineries Electrodes for electrolysis

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Acid & Base

Acid	Base
Strong Acid: _____ in water to form hydrogen ions Weak Acid: _____ in water to form hydrogen ions	Strong Alkali: _____ in water to form hydroxide ions Weak Alkali: _____ in water to form hydroxide ions
1. Sour 2. Corrosive 3. Less than pH 7 4. Turns blue litmus paper red	1. Bitter 2. Soapy feel 3. More than pH 7 4. Turns red litmus paper blue
1. Reactive metal reacts with acid to form a salt and hydrogen gas. 2. Metal oxide reacts with acid to form a salt and water 3. Metal hydroxide reacts with acid to form a salt and water. 4. Metal carbonate reacts with acid to form salt, water and carbon dioxide.	1. Reacts with ammonium compounds to release ammonia gas 2. Reacts with ionic compounds to form metal hydroxide

Common pH Indicators

pH	1	2	3	4	5	6	7	8	9	10	11	12	13
Methyl Orange	Red					Yellow							
Phenolphthalein	Colourless								Pink				
Universal Indicators	Red		Orange		Yellow		Green	Blue		Violet			
Compounds:	HC*l*			CH_3COOH			H_2O NaC*l*				NH_3		NaOH

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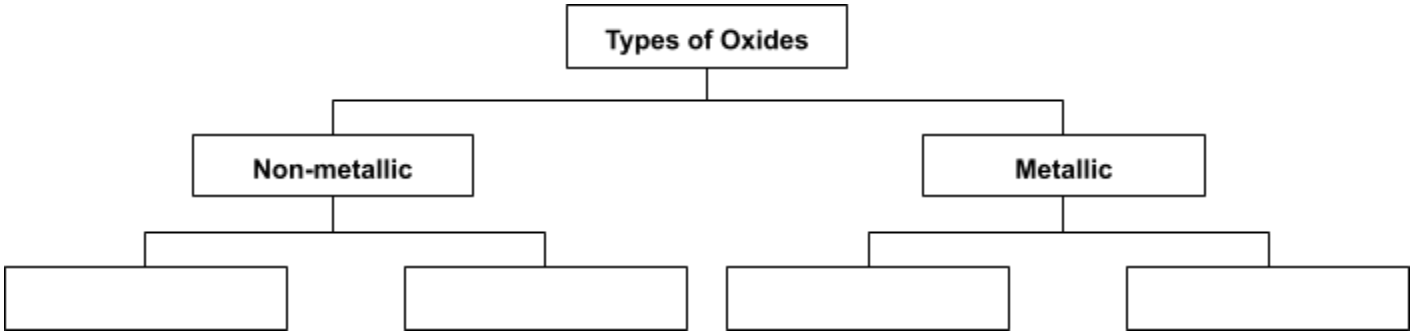


Ammonia

Uses of ammonia:

Process	Reactions & Remarks	Conditions
Haber Process		

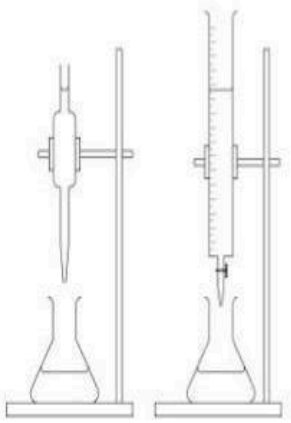
Related Questions:

1. Sources of raw materials for Haber process?

2. Why is it not recommended to use air (78% N_2) for Haber process?

Pure Chemistry Intensive: Inorganic Chemistry

Salt Preparation

Crystallisation	Precipitation	Titration
To extract soluble salt (e.g. $MgCl_2$)	To extract insoluble salt (e.g. $PbCl_2$)	To extract alkali salts (e.g. $NaCl$, NH_4NO_3)
1. Add excess metal oxide (MgO) to acid (HCl) 2. Filter away excess metal oxide 3. Heat the filtrate till saturated 4. Cool the saturated solution 5. Filter the crystals 6. Blot dry	1. Add metal nitrate ($Pb(NO_3)_2$) to acid (HCl) 2. Filter the mixture 3. Wash the residue ($PbCl_2$) with distilled water 4. Blot dry	1. Drop two drops of methyl orange into conical flask 2. Fill the conical flask with 25.0 cm^3 acid using a pipette 3. Fill burette with alkali and note initial reading (V_0 cm^3) 4. Add alkali dropwise until change of colour is observed in solution of conical flask (endpoint). Note final reading (V_1 cm^3) 5. Volume of alkali required is ($V_0 - V_1$) cm^3 6. Repeat steps 2 to 4 with ($V_0 - V_1$) cm^3 of alkali. 

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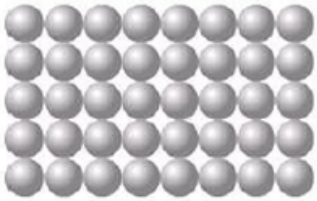
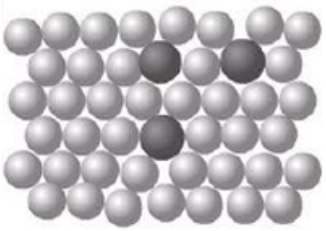
Pure Metals & Alloys

Reactivity Series of Metals

	Reaction with cold water	Reaction with steam	Reaction with dilute acid	Extraction Method
Potassium				
Sodium				
Calcium				
Magnesium				
Aluminium				
Zinc				
Iron				
Lead				
Copper				
Silver				

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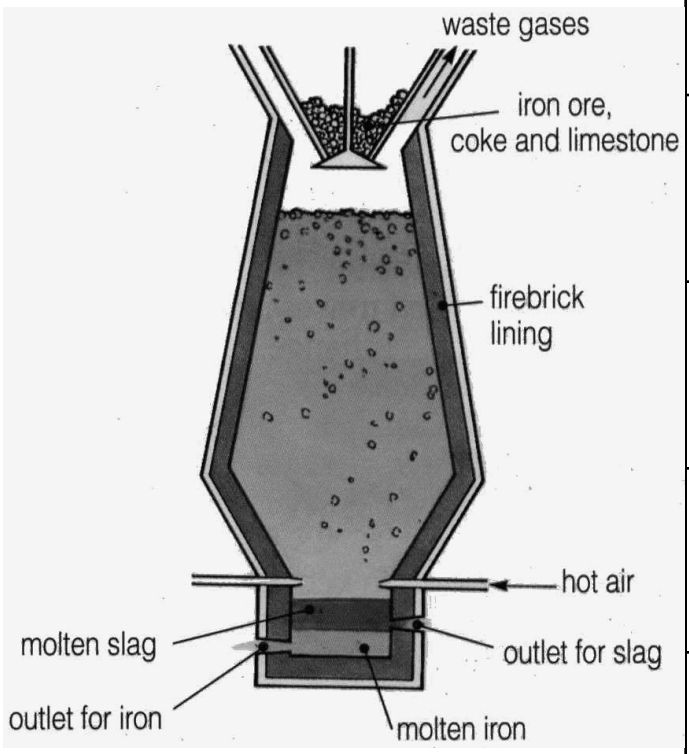
Extraction of Iron



Coke reacts with oxygen in air to form carbon dioxide.

Carbon dioxide reacts with more coke to form carbon monoxide.

Carbon monoxide reacts with haematite to form molten iron.

Limestone undergoes thermal decomposition to form quicklime and carbon dioxide.

Quicklime reacts with sand (_____) to form slag (_____)

Protection of Iron

Coating	Sacrificial Protection
Prevents iron from coming into contact with _____.	Attach more reactive metal

Reasons for Recycling of Metals

1. Metals are finite resources
2. Cheaper
3. Causes less pollution
4. Uses less energy

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Oxidation states:

<table>
<tr><th></th><th>Examples</th></tr>
<tr><td>As an <u>element</u>, the oxidation state is always zero.</td><td>Oxidation state of N in N_2:

Oxidation state of iron in Fe:</td></tr>
<tr><td>When reacted, <u>alkali metals (group I)</u> will have an oxidation state of +1.
Group II metals will have oxidation state of +2</td><td>Oxidation state of sodium in Na in NaCl:

Oxidation state of magnesium in $MgSO_4$:</td></tr>
<tr><td>The oxidation state of <u>hydrogen</u> depends on its partner.</td><td><table><tr><th>Type</th><th>Examples</th><th>Oxidation state</th></tr><tr><td>Metal</td><td>NaH, MgH_2</td><td></td></tr><tr><td>Non-metal</td><td>NH_3, H_2O_2, NaOH</td><td></td></tr></table></td></tr>
<tr><td>To know the state of oxygen, take note of its name of the anions.</td><td><table><tr><th>Anion Name</th><th>Examples</th><th>Oxidation state</th></tr><tr><td>Oxide</td><td>Na_2O, NaOH</td><td>-2</td></tr><tr><td>Peroxide</td><td></td><td></td></tr><tr><td>Superoxide</td><td></td><td></td></tr></table></td></tr>
</table>

Redox Reaction

<table>
<tr><th>Reduction</th><th>Oxidation</th><th>Equations</th></tr>
<tr><td>1. Oxygen
2. Oxidation state
3. Hydrogen
4. Electrons</td><td>1. Oxygen
2. Oxidation state
3. Hydrogen
4. Electrons</td><td></td></tr>
<tr><td><u>Common oxidising agents:</u>
1. Potassium manganate (VII)

2. Potassium dichromate (VI)</td><td><u>Common reducing agents:</u>
1. Potassium iodide

2. Reactive metals</td><td></td></tr>
</table>

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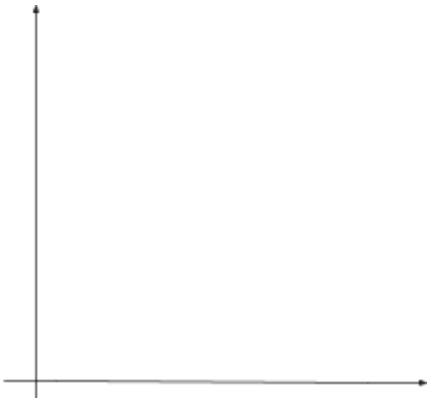
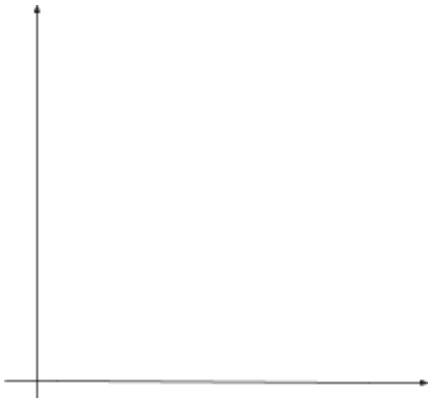
Pure Chemistry Intensive: Inorganic Chemistry

Energy Change

Exothermic Reaction	Endothermic Reaction
_____ energy is _____ from bond forming than energy _____ from bond breaking.	_____ energy is _____ from bond forming than energy _____ from bond breaking.
	
Physical Processes: Freezing, condensation Chemical Processes: Neutralisation Burning/ Combustion Respiration	

Transition Metals as Catalyst:

Transition metals are metals with the following properties:

1.

2.

3.

Catalyst speeds up reactions without _____ changing itself at the end of the reaction.

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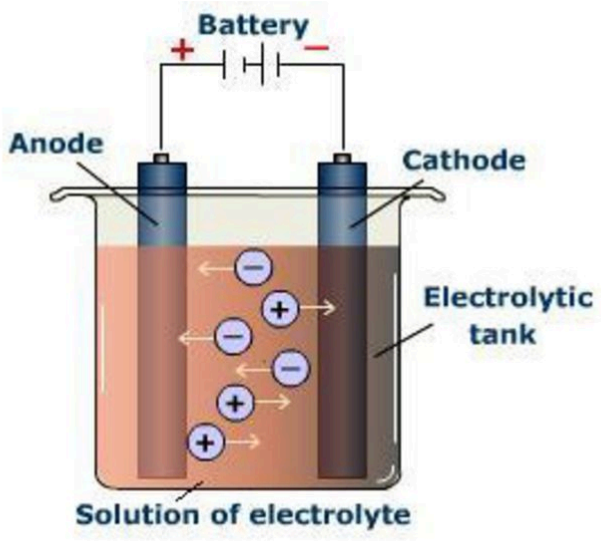
Pure Chemistry Intensive: Inorganic Chemistry

Electrolysis

Important Notes:

1. Inert electrodes: _____
2. Discharging of Cations: _____
3. Discharging of Anions
    - Diluted solution
    - Concentrated halide solution

Electrolytic Cell (Inert electrodes):



Electrolyte	Concentrated sodium chloride solution	Diluted sodium chloride solution
Ions in electrolyte		
Anode Reaction		
Cathode Reaction		
Overall Reaction		
Observation (pH/ Colour)		

Copper Plating ($CuSO_4$ electrolyte):

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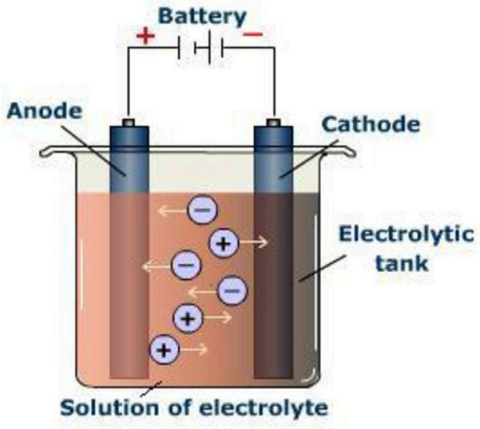
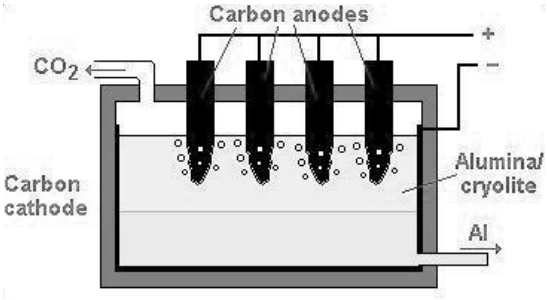


Electrodes	Copper	Graphite
Ions in electrolyte		
Anode Reaction		
Cathode Reaction		
Overall Reaction		
Observation (pH/ Colour)		

Application: Extraction of Reactive Metal (Aluminium)

Melting point of aluminium oxide (bauxite): 2000 °C

Melting point of cryolite (Na_3AlF_6): 1000 °C



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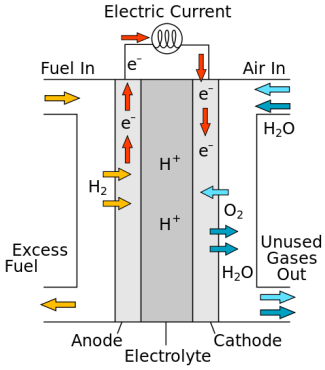
Pure Chemistry Intensive: Inorganic Chemistry

Simple Cell:

Electrolyte	**Concentrated sodium chloride (Copper and silver electrodes)	Dilute iron (II) nitrate (Aluminium, iron electrodes)
Ions in electrolyte		
Anode Reaction		
Cathode Reaction		
Overall Reaction		
Observation (pH/ Colour)		



Application: Hydrogen Fuel Cell

Electrolyte: KOH

Anode (Half Equation): $2H_2 + 4OH^- \rightarrow 4H_2O + 2e^-$

Cathode (Half Equation): $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Overall Equation: _____

Advantage: Products (water) does not pollute the environment.

Disadvantage: Process of obtaining raw materials (H_2) pollutes the environment.

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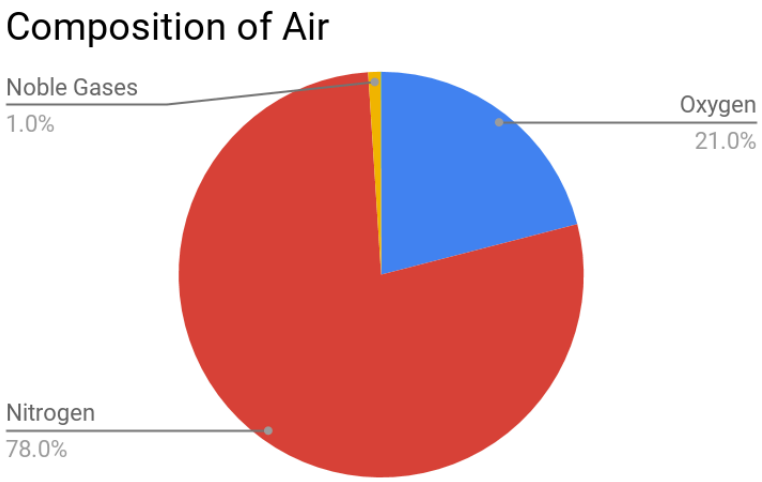
Pure Chemistry Intensive: Inorganic Chemistry

Atmosphere



I. Atmosphere & Air

Air Pollutants	Sources	Effects
Oxides of nitrogen		Forms acid rain which affects pH of soil and water bodies resulting in death of plants and marine organisms. Throat irritation & airway inflammation.
Sulfur dioxide		Forms acid rain which affects pH of soil and water bodies resulting in death of plants and marine organisms. Throat irritation & airway inflammation.
Carbon monoxide		Reacts with haemoglobin in blood to reduce transportation in human body.
Methane	Decay of organic matter	Greenhouse gas that results in global warming.
Unburnt hydrocarbon		Carcinogenic. Reacts with ozone to form photochemical smog.
Ozone		Throat irritation & airway inflammation. Reacts with unburnt hydrocarbon to form photochemical smog.
Carbon Dioxide		Greenhouse gas that results in global warming.

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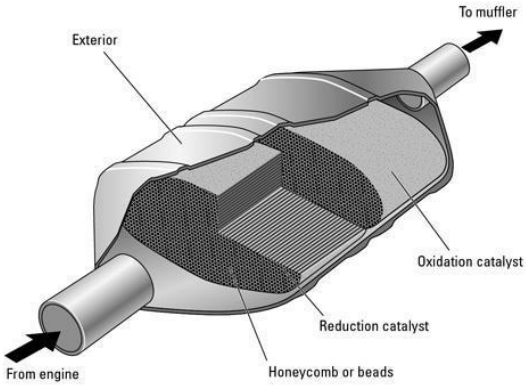
Pure Chemistry Intensive: Inorganic Chemistry

Ways of reducing air pollution:

Catalytic Converter

Problems of vehicle exhausts:

- High temperature forms oxides of nitrogen
- Incomplete combustion of fuel



Features of catalytic converter:

1. Honey-combed structure
2. Platinum and rhodium catalyst

Reactions that occur in catalytic converter:

1. Oxides of nitrogen reacts with carbon monoxide
2. Complete combustion of soot, unburnt hydrocarbons & carbon monoxide

Advantages	Limitations
Harmful pollutants such as oxides of nitrogen, carbon monoxide and unburnt hydrocarbon is reduced.	Unable to reduce sulfur dioxide or carbon dioxide content.

Flue Gas Desulfurisation (FGD)

Main Reactant:

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Carbon Footprint:

The amount of carbon dioxide released into the atmosphere as a result of human activities.

- Using ethanol (biofuel) instead of fossil fuels

Production of ethanol from plants involves photosynthesis which removes carbon dioxide from the atmosphere. Since the amount of carbon dioxide absorbed is equal to its release, fuel is considered carbon neutral.

Limitations of carbon-neutral fuels:

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Pure Chemistry Intensive: Inorganic Chemistry

List of Common Reactions

Reaction	Remarks	Example Equation
Dissociation	Occurs when acid is dissolved in water. H^+ ions produced.	$HCl \rightarrow H^+ + Cl^-$
Neutralisation	Acid reacts with base to form salt	$H^+ + OH^- \rightarrow H_2O$ $2H^+ + O^{2-} \rightarrow H_2O$ $2H^+ + CO_3^{2-} \rightarrow CO_2 + H_2O$
Haber Process	Process to produce ammonia. (250 atm., 450°C, finely divided iron catalyst)	$N_2 + 3H_2 \quad 2NH_3$
Precipitation	Reaction that produces precipitate.	$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$
Titration	Reaction occurs for SPA salts (sodium, potassium and ammonium salts)	$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$
Displacement	Occurs when a more reactive element displaces the less reactive element from its compound.	$Zn + Cu^{2+} \rightarrow Cu + Zn^{2+}$ $Cl_2 + 2KI \rightarrow 2KCl + I_2$
Ionisation	Compound (dissolves in water) to form ions.	$Na \rightarrow Na^+ + e^-$
Redox	Occurs when the factors below happen: 1. Number of oxygen atoms changes 2. Number of hydrogen atoms changes 3. Number of electrons changes 4. Oxidation state changes	$C + O_2 \rightarrow CO_2$ $Mg + Cu^{2+} \rightarrow Cu + Mg^{2+}$
Combustion/ Burning	Substance reacts with oxygen and a flame is observed.	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
Rusting	When iron oxidises to form rust (Fe_2O_3)	$4Fe + 3O_2 \rightarrow 2Fe_2O_3$
Thermal Decomposition	Substance breaks into simpler substances in the presence of heat.	$CaCO_3 \rightarrow CaO + CO_2$
Exothermic	Heat is released, temperature increases. (Energy released for bond forming greater than energy absorbed for bond breaking)	$C + O_2 \rightarrow CO_2$
Endothermic	Heat is absorbed, temperature decreases.	$CaCO_3 \rightarrow CaO + CO_2$

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Electrolysis	Discharging of ions from electrolytes using electricity.	Refer to the electrolysis chapter.
Photosynthesis	Occurs in the presence of chlorophyll. Light is required to activate the reaction. (Endothermic)	$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
Respiration	Reverse process of photosynthesis, similar to oxidation. (Exothermic)	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
Flue Gas Desulfurisation	Removal of sulfur/ sulfur dioxide from gas exhaust. (Neutralisation)	$SO_2 + CaCO_3 \rightarrow CaSO_3 + CO_2$ $2CaSO_3 + O_2 \rightarrow 2CaSO_4$