Group 15 (Nitrogen Family)

* Physical properties
* chemical properties
* Chemistry of Nitrogen ⇒ N_2, NH_3, oxides of nitrogen & oxyacids of nitrogen (HNO_3)
* chemistry of Phosphorous ⇒ Allotropes, oxides, oxy acids & halides of P.

Physical properties

General EC : $ns^2 np^3$ (extra stable)

Electronic configuration & Metallic & Nonmetallic characters

		Atomic no	EC	Inner core.
Metal	N	7	[He] $2s^2$ $2p^3$	Noble gas
	P	15	[Ne] $3s^2$ $3p^3$	
Metalloids	As	33	[Ar] $3d^{10}$ $4s^2$ $4p^3$	Pseudo Noble gas
	Sb	51	[Kr] $4d^{10}$ $5s^2$ $5p^3$	
Metal	Bi	83	[Xe] $4f^{14}$ $5d^{10}$ $6s^2$ $6p^3$	$d^{10}+f^{14}$+NG

on going dow the group metallic character of elements increases.

Bi ⇒ Last Stable non-Radio active element

2) Nature & Allotropy

N_2 is a colourless, diatomic gas & does not show Allotropy

Remaining all element (P, As, Sb, Bi) are solids and shows allotropy

P_4 - Soft solid Allotropes: white, Red & Black Phosphorous

$N \equiv N$ ⇒ Due to very strong triple bond in N_2 it is an Inert gas.

Bond Strength : $N-N < P-P$

N has less tendency to undergo catenation.

Atomic size

On moving down the group atomic size Increases

$N < P < As < Sb < Bi$

(In Pm) 70 110 121 141 148

Variation is less due to Lanthanide Contraction.

Ionization enthalpy

On moving down the group IE ↓ses due to ↑se in atomic size.

IE : $N > P > As > Sb > Bi$

* Group 15 elements 1st Ionisation enthalpy is higher as compared to Group 16

IE : Group 15 ($ns^2 np^3$) > Group 16 ($ns^2 np^4$)

* For Group 15 elements:

$\Delta_i H_1 < \Delta_i H_2 < \Delta_i H_3$

1st IE, 2nd IE, 3rd IE

$N \rightarrow N^+ + \bar{e}$

$N^+ \rightarrow N^{2+} + \bar{e}$

$N^{2+} \rightarrow N^{3+} + \bar{e}$

Electronegativity

On going down the group EN ↓ses

N	> P	> As	> Sb	> Bi
3	2.1	2	1.9	1.9

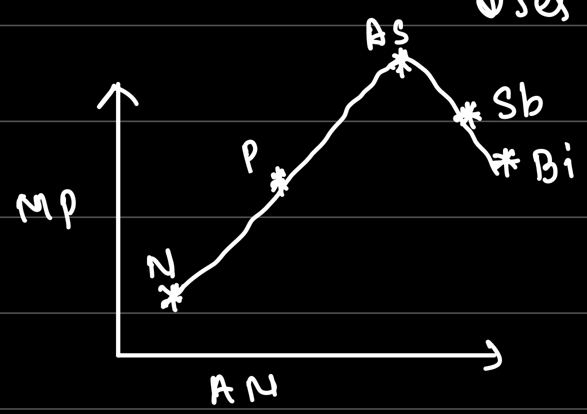
Density

Density increases down the group.

Density: N < P < As < Sb < Bi

Melting point and Boiling point

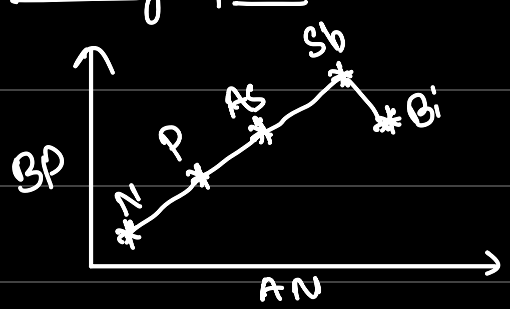
Melting point : MP ↑ses from N to As then ↓ses to Bi



N < P < Bi < Sb < As

highest MP

Boiling point : BP ↑ses from N to Sb then ↓ses to Bi



BP : N < P < As < Bi < Sb

highest BP

Chemical properties

Oxidation number

Most common oxidation state of Group 15 elements.

: +5, +3, −3

* tendency to show −3 oxidation state decreases down the group due to ↑sed size & ↑sed metallic character. Bi rarely shows −3 oxidation state.

tendency to show −3 OS : N > P > As > Sb > Bi

* N also shows +1, +2 & +4 OS.

$\overset{-3}{N}H_3$ $\quad \overset{-2}{N_2}H_4$ $\quad \overset{-1}{N_2}H_2$ $\quad \overset{0}{N_2}$ $\quad \overset{+1}{N_2}O$ $\quad \overset{+2}{N}O$ $\quad \overset{+3}{N_2}O_3$

$\overset{+4}{N_2}O_4$ $\quad \overset{+5}{N_2}O_5$

* N with oxidation state +1 to +4 tends to disproportionate in acid solution.

$$3H\overset{+3}{N}O_2 \longrightarrow H\overset{+5}{N}O_3 + 2\overset{+2}{N}O + H_2O$$

* P can also show +1 & +4 OS in some of its oxy acids.

$H_3\overset{+1}{P}O_2$ $\quad H_3\overset{+3}{P}O_3$ $\quad H_3\overset{+5}{P}O_4$ $\quad H_4\overset{+5}{P_2}O_7$ $\quad H_4\overset{+4}{P_2}O_6$

all Intermediate OS tends to disproportionate into +5 & -3 in both acid & alkali solution.

* tendency to show +3 OS ↑ses down the group. due to Inert pair effect.

2) Reactivity towards Hydrogen

All elements readily combines with Hydrogen to form hydride of the type MH_3

$$2M + 3H_2 \longrightarrow 2MH_3$$

* thermal stability of hydrides decreases down the group. due to ↓se in Bond strength M-H (ie, Bond dissociation energy of M-H ↓ses down the group.

thermal stability order:

$$\ddot{N}H_3 > \ddot{P}H_3 > \ddot{As}H_3 > \ddot{Sb}H_3 > \ddot{Bi}H_3$$

3P-1S 4P-1S 5P-1S 6P-1S

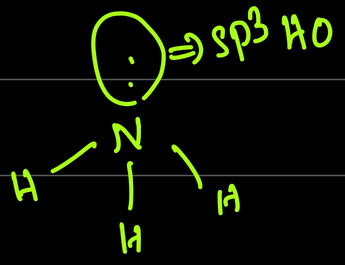
⇓ sp3 Hybridisation

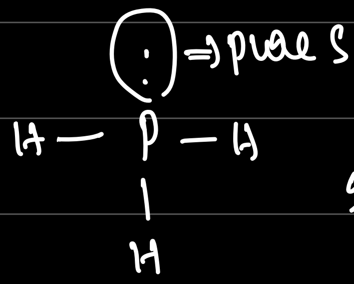
⇓ Do not undergo Hybridisation, Pure p orbitals directly overlap with 1s orbitals of H. having a range of BA 90-93°

* Reducing character of Hydrides ↑ses down the group.

$NH_3 < PH_3 < AsH_3 < SbH_3 < BiH_3$

Very mild RA (strongest RA)

* 



% s character $\propto$ EN

Basicity of Hydrides ↓ses down the group.

$NH_3 > PH_3 > AsH_3 > SbH_3 \gtrsim BiH_3$

* NH_3 shows Hydrogen bonding in solid as well as in liquid state, so its MP & BP are comparatively higher.

BP & MP ↑ses down the group

BP : $PH_3 < AsH_3 < NH_3 < SbH_3 < BiH_3$

MP : $PH_3 < AsH_3 < SbH_3 < NH_3$

* Bond length : $N-H < P-H < As-H < Sb-H < Bi-H$

Bond angle : $NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3$

107.8 93.6 91.8 91.3

$\Delta_f H$: $NH_3 < PH_3 < AsH_3 < SbH_3 < BiH_3$

(KJ/mol) -46.1 $\underbrace{13.4 \quad 66.4 \quad 145.1 \quad 278}_{\text{endothermic}}$

⇓ exothermic

Bond dissociation energy : $\Delta H_{dissociation}$ ↓ses down the group.

⇒ NH_3 exist but NH_5 does not exist (due to absence of d orbitals in N)

⇒ PH_3 exist but PH_5 does not exist. (H is not sufficiently electronegative to bring excitation of $\bar{e}$ to d orbitals)

3) Reactivity towards oxygen

All these elements forms two types of oxide on directly combining with O_2 ⇒ M_2O_3 & M_2O_5

$$4M + 3O_2 \rightarrow 2M_2O_3$$

$$4M + 5O_2 \rightarrow 2M_2O_5$$

oxides of N	:	N_2O	NO	N_2O_3	N_2O_4 (dimer of NO_2)	N_2O_5
P	:			P_4O_6 (dimer of P_2O_3)		P_4O_{10} (dimer of P_2O_5)

* Basic character of oxides ↑ses down the group.

$$\underbrace{N_2O_3 < P_4O_6}_{\text{Acidic}} < \underbrace{As_2O_3 < Sb_2O_3}_{\text{Amphoteric}} < \underset{\text{Basic}}{Bi_2O_3}$$

* Stability of +5 OS oxides ↓ses down the group (Inert pair effect)

M^{+3} OS is less acidic than M^{+5}.

N_2O_5 is more acidic than N_2O_3.

4) Reactivity with Halogens

All elements combines directly with X_2 to form two types of Halides MX_3 & MX_5
(except N & Bi)

NX_5 does not exist (N can not show covalency more than 4 due to absence of d orbitals)

Bi does not show stable +5 OS due to Inert pair effect.

$$2M + 3X_2 \longrightarrow 2MX_3$$

$$2M + 5X_2 \longrightarrow 2MX_5$$

* Penta halides more covalent than trihalides.
* In trihalides except BiF_3 everything are covalent
  $BiF_3 \Rightarrow$ has Ionic character.
* In trihalides of Nitrogens, only NF_3 is stable.

5) Reactivity towards metal

All these elements can react with metal to form their binary compounds exibiting −3 OS.

eg :

Ca_3N_2 , Ca_3P_2, Na_3As, Zn_3Sb_2, Mg_3Bi_2

Compounds of Nitrogen

Air contains around 78 % by volume of N_2 gas.

* N_2 is produced commercially by the liquefaction and fractional distillation of air.

Liquide N_2 (BP = 77.2 K) distills out first leaving behind liquid O_2 (BP = 90 K)

Laboratory method

treating aqueous solution of ammonium chloride with sodium nitrite.

$$NH_4Cl_{(aq)} + NaNO_{2(aq)} \longrightarrow N_{2(g)} + NaCl + 2H_2O.$$

⇒ this reaction occurs in two step.

$$NaNO_2 + NH_4Cl \longrightarrow NaCl + NH_4NO_2$$

$$\text{(imp)}\quad \overset{-3}{N}H_4\overset{+3}{N}O_2 \xrightarrow{\Delta} \overset{0}{N}_{2(g)} + 2H_2O \quad \text{(comproportionation)}$$

$$NH_4Cl + NaNO_2 \longrightarrow N_2 + NaCl + 2H_2O$$

* By heating Ammonium dichromate

oxidation

Reduction.

$$\overset{-3}{(NH_4)_2}\,\overset{+6}{Cr_2}O_7 \xrightarrow{\Delta} \overset{0}{N_2}{}_{(g)} + \overset{+3}{Cr_2}O_3 + 4H_2O$$

Orange $\qquad\qquad\qquad\qquad$ Green

* Very purest of N_2 is obtained by heating. Sodium or Barium Azide.

$$2NaN_3 \xrightarrow{\Delta} 2Na + 3N_{2(g)}$$

$$Ba(N_3)_2 \longrightarrow Ba + 3N_{2(g)}$$

Properties of N_2

* N_2 is colourless, odourless, tasteless and Non toxic gas
* It has low solubility in water.
* It has Low Freezing point & Boiling point.
* N_2 is inert at room temperature, due to high. Bond enthalpy of $N\equiv N$
* At higher temperature, N_2 directly combines with metals and Nonmetals to form Ionic Nitride & covalent nitrides respectively.

$$\left.\begin{array}{l} 2Li + N_2 \xrightarrow{\Delta} 2Li_3N \\ 3Mg + N_2 \longrightarrow Mg_3N_2 \end{array}\right]$$ Diagonal relationship.

(Haber's process) $3H_2 + N_2 \rightleftharpoons 2NH_3 \quad \Delta_f H = -ve.$

(exothermic

$$N_2 + O_2 \xrightarrow[2000K]{\Delta} 2NO \quad \Delta H = +ve$$

(endothermic)

Uses of N_2

* used for manufacture of NH_3 & other industrial chemicals containing nitrogen (eg: calcium cyanamide etc)

* It is used to provide inert atmosphere in industrial processes, where presence of O_2 or air is avoided.
* Liquid N_2 is used as a refrigerant to preserve biological materials, food items etc.

Ammonia (NH_3)

Preparation

Laboratory method.

* By action of Any base on NH_4^+ salt.

$$2NH_4Cl + Ca(OH)_2 \rightarrow 2NH_3 + 2H_2O + CaCl_2$$

$$(NH_4)_2SO_4 + \underset{\text{(caustic Soda)}}{2NaOH} \rightarrow 2NH_3 + 2H_2O + Na_2SO_4$$

* By hydrolysis of Nitrides.

$$AlN + 3H_2O \rightarrow Al(OH)_3 + NH_3$$

$$Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$$

* By hydaolysis of uaea.

$$NH_2CONH_2 + 2H_2O \longrightarrow (NH_4)_2CO_3 \xrightarrow{\Delta} 2NH_3 + H_2O + CO_2$$

Quantitative estimation of ammonia

$$NO_2^- / NO_3^- \xrightarrow[NaOH]{Zn} NH_3\uparrow$$

$$\overset{+3}{NaNO_2} + 5NaOH + 3\overset{0}{Zn} \longrightarrow 3Na_2\overset{+2}{Zn}O_2 + \overset{-3}{N}H_3 + H_2O$$

$$Na\overset{+5}{N}O_3 + 7NaOH + 4\overset{0}{Zn} \longrightarrow 4Na_2\overset{+2}{Zn}O_2 + \overset{-3}{N}H_3 + 2H_2O$$

Industaial method - Habea's paocess.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H = -ve.$$

Foa bettea yield of NH_3

* High P (200 atm)
* low temp ($500^\circ C$) ⇒ min temp aequiaed.

* catalyst – Iron oxide with a small amount of K_2O & Al_2O_3.

② * By Hydrolysis of cyanamide

$$CaO + 2C + N_2 \xrightarrow{\text{high temp.}} CaCN_2$$

$CN_2^{2-} \Rightarrow$ cyanamide $\quad {}^{\ominus}:\ddot{N}=C=\ddot{N}:^{\ominus}$

$$CaCN_2 + 3H_2O \longrightarrow CaCO_3 + 2NH_3\uparrow$$

Drying of Moist NH_3

$$\underset{\text{(moist)}}{NH_3} \xrightarrow[\text{agent}]{\text{dehydrating}} \underset{\text{(dry)}}{NH_3}$$

Dehydrating agent like conc. H_2SO_4, P_4O_{10}, anhydrous $CaCl_2$ can not be used for drying moist NH_3

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

$$P_4O_{10} + 12NH_3 + 6H_2O \longrightarrow 4(NH_4)_3PO_4.$$

$$8NH_3 + CaCl_2 \longrightarrow \underset{\text{Complex.}}{CaCl_2 \cdot 8NH_3}$$

* Quick lime (CaO) is used for drying of NH_3.

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

Properties of NH_3

* It is a colourless gas pungent smell.
* Its freezing & Boiling point are 198.4 239.7 K respectively.
  Because In solid & liquid state It can show H bonding.
* It is soluble in water to significant extent In aqueous solution, It is basic In nature.

  $$NH_3 + H_2O \longrightarrow NH_4OH \rightleftharpoons NH_4^+ + OH^-$$

It is A weak Lewis base as well as Bronsted base.
So, It can react with acid & form salt

$$NH_3 + HCl \longrightarrow NH_4Cl$$

$$3NH_3 + H_3PO_4 \longrightarrow (NH_4)_3PO_4$$

Reaction of NH_3 with Salt

* It can react with salts & produce Insoluble hydroxide.

$PbCl_2 + 2NH_4OH \rightarrow Pb(OH)_2\downarrow + 2NH_4Cl$
white.

$FeCl_3 + 3NH_4OH \rightarrow Fe(OH)_3\downarrow + 3NH_4Cl$
Reddish brown

* on reaction with Zn it can form soluble complex.

$ZnCl_2 + 2NH_4OH \rightarrow Zn(OH)_2\downarrow + 2NH_4Cl$
white

$Zn(OH)_2 + 2NH_4Cl + 2NH_4OH$
$\rightarrow [Zn(NH_3)_4]Cl_2 + 4H_2O$
soluble.

* NH_3 can form complex

$CuSO_4 + 4NH_3 \rightarrow [Cu(NH_3)_4]SO_4$.
$AgCl + 2NH_3 \rightarrow [Ag(NH_3)_2]Cl$.

Heating effect of Ammonium salts

Generally Ammonium salts on heating gives NH_3 gas.

$NH_4Cl \xrightarrow{\Delta} NH_3 + HCl$
$(NH_4)_2SO_4 \xrightarrow{\Delta} 2NH_3 + H_2O + SO_3$

$$(NH_4)_2CO_3 \xrightarrow{\Delta} 2NH_3 + H_2O + CO_2.$$

※

$$NH_4NO_2 \xrightarrow{\Delta} N_2 + 2H_2O$$

$$(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} N_2 + Cr_2O_3 + 4H_2O$$

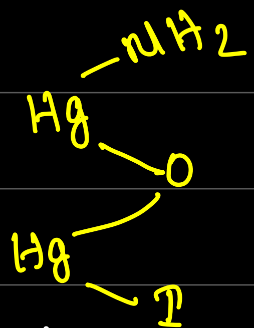
$$NH_4NO_3 \xrightarrow{\Delta} N_2O + 2H_2O$$

Test for NH_3

When NH_3 gas is passed through an alkaline solution of Nessler's reagent $[K_2[HgI_4]]$, Brown precipitate or Brown colour is obtained.

$$2K_2HgI_4 + 3KOH + NH_3$$

$$\downarrow$$



$$+ 7KI + 2H_2O$$

Iodide of millon's base

Uses of NH_3

* Used as a refrigeratory liquid.
* For manufacturing of fertilizers

* As a starting material for preparation of HNO_3 by Ostwaald's process
* Used as a laboratory reagent.

* N_2O + NaOH ⟶ No rxn.
  Neutral

  NO + NaOH ⟶ No rxn.
  Neutral

  $\overset{+3}{N_2O_3} + 2NaOH \longrightarrow 2NaNO_2 + H_2O$

  $N_2O_5 + CaO \longrightarrow Ca(NO_3)_2$

  $\overset{+4}{N_2O_4} + 2NaOH \longrightarrow NaNO_2 + NaNO_3 + H_2O.$

Oxyacids of Nitrogen

$H\overset{+3}{N}O_2$ ⇒ Nitrous acid

$H\overset{+5}{N}O_3$ ⇒ Nitric acid.

$H_2\overset{+1}{N_2}O_2$ ⇒ Hyponitrous acid.

Nitric acid (HNO_3)

Laboratory Method

$$2NaNO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + 2HNO_3$$

Industrial Method

On large scale HNO_3 is prepared by Ostwaald's process.

Step I ⇒ Catalytic oxidation of NH_3 by atmospheric oxygen.

$$4NH_3 + 5O_2 \xrightarrow[500K,\ 9\,bar]{Pt/Rh \Rightarrow Catalyst} 4NO_{(g)} + 6H_2O.$$

Step II ⇒ Nitrous oxide formed combines with O_2 & form NO_2

$$2NO + O_2 \rightleftharpoons 2NO_2.$$

Nitrogen dioxide is dissolved in water to for HNO_3.

$$3\overset{+4}{N}O_2 + H_2O \longrightarrow 2HNO_3 + NO.$$

⇒ aqueous HNO_3 can be concentrated by distillation up to 68% of HNO_3 by mass. & with specific gravity 1.504

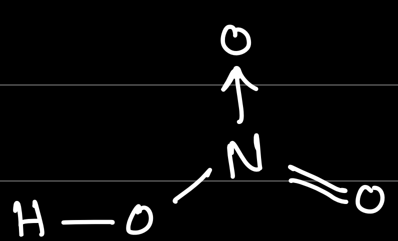
* 98% HNO_3 can be obtained by dehydrating with conc. H_2SO_4.

Properties of HNO_3

* It is a colourless liquid with $FP = 231.4K$

$bP = 355.6K$.

* In gaseous state It exist as a planar molecule.



sp^2 ⇒ trigonal planar Geometry.

* Aqueous solution of HNO_3 behaves as a strong acid.

$$HNO_3 + H_2O \longrightarrow H_3O^+ + NO_3^-$$

* Conc. HNO_3 is a strong oxidising agent & can attack most metals except Au & Pt. Product of oxidation depends on concentration of the acid, temperature, & the nature of material undergoing oxidation.

HNO_3 on Reaction with Non metals.

$$I_2 \xrightarrow{HNO_3} HIO_3$$
$$C \xrightarrow{HNO_3} CO_2$$
$$S_8 \xrightarrow{HNO_3} H_2SO_4$$
$$P_4 \xrightarrow{HNO_3} H_3PO_4.$$
$$HNO_3 \longrightarrow NO_2$$

* On Reaction with metal Mn, Mg HNO_3 can produce H_2 gas

$$Mg + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2$$

$Mn + 2HNO_3 \longrightarrow Mn(NO_3)_2 + H_2$

* Metals which are placed above hydrogen in electrochemical series

Fe & Zn react with very dil. $HNO_3 \rightarrow NH_4NO_3$

dil. $HNO_3 \rightarrow N_2O$

conc. $HNO_3 \rightarrow NO_2$.

$$\overset{0}{4Zn} + \underset{\text{very dilute.}}{10\overset{+5}{HNO_3}} \longrightarrow 4\overset{+2}{Zn}(NO_3)_2 + \overset{-3}{N}H_4NO_3 + 3H_2O$$

$$\overset{0}{Fe} + \underset{(dil)}{\overset{+5}{HNO_3}} \longrightarrow \overset{+2}{Fe}(NO_3)_2 + \overset{+1}{N_2}O + H_2O$$

$$\overset{0}{Fe} + \underset{(conc)}{\overset{+5}{HNO_3}} \longrightarrow \overset{+2}{Fe}(NO_3)_2 + \overset{+4}{N}O_2 + H_2O.$$

Sn + very dil. $HNO_3 \longrightarrow Sn(NO_3)_2 + NH_4NO_3$

Sn + conc. $HNO_3 \longrightarrow \underset{\text{meta stannic acid}}{H_2SnO_3} + NO_2$

* Be, Fe, Co, Ni, Ca, Al these metals become passive with conc. HNO_3 due to thin layer of oxide on their surface.

* Metals placed below H in electrochemical series.

Cu, Ag, Hg, Pb

$$\text{conc.}\,HNO_3 \longrightarrow NO_2$$

$$\text{dil.}\,HNO_3 \longrightarrow NO$$

$$\underset{(\text{conc})}{Cu + 4HNO_3} \longrightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O.$$

$$\underset{(\text{dil})}{Cu + 8HNO_3} \longrightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O.$$

* On reaction of HNO_3 with metalloid.

$$Sb \downarrow H_3SbO_4 \qquad As \downarrow H_3AsO_4$$

$$\text{conc.}\,HNO_3 \longrightarrow NO_2.$$

$$Sb + 5HNO_3 \longrightarrow H_3SbO_4 + 5NO_2 + H_2O$$

* Au & Pt dissolves only in aqua regia

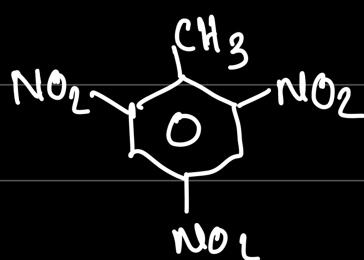
($HNO_3 : HCl$ 1 : 3 mixture } aqua regia)

Use

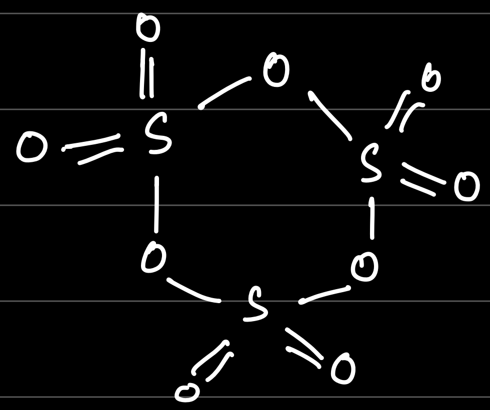
⇒ Manufacture of NH_4NO_3 for fertilizers, other nitrates & for explosives

TNT

trinitro toluene



* It is used as an oxidiser in Rocket fuel.



Oxygen Family [Group 16]

Physical Properties

Electronic Configuration, Metallic & Non metallic character.

General EC : $ns^2\ np^4$

		Atomic no	EC	Inner core
Nonmetal	O	8	[He] $2s^2\ 2p^4$	Inert gas
	S	16	[Ne] $3s^2\ 3p^4$	
Metalloids	Se	34	[Ar] $3d^{10}\ 4s^2\ 4p^4$	Pseudo Inert gas
	Te	52	[Kr] $4d^{10}\ 5s^2\ 5p^4$	
Metal ⇐	Po	84	[Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p^4$	

⇓ $t_{1/2} = 13.8$ days.

Radioactive. [$Z \geq 84$ all are radioactive]

On moving down the group metallic character ↑ses.

Atomic Size / Ionic Size (E^{2-})

Atomic size or Ionic size ↑ses down the group because of ↑se in no. of shells.

AS / IS : $O < S < Se < Te$

Ionisation enthalpy

Ionisation enthalpy ↓ses down the group due to ↑se in atomic size.

IE : $O > S > Se > Te$

1st IE

Group 15 > Group 16.

Melting point & Boiling point

MP & BP ↑ses down the group.

MP : $O < S < Se < \underline{Po < Te}$

BP : $O < S < Se < \underline{Po < Te}$.

Density

Density ↑ses down the group

$O < S < Se < Te$.

Electronegativity

EN ↓ses down the group.

EN:	$O >$	$S >$	$Se >$	$Te. >$	Po
	3.5	2.58	2.55	2.01	1.76

Electrongain enthalpy

$\Delta_{eg}H$ ↓ses down the group.

$O + \bar{e} \longrightarrow O^-$ (exothermic)

$O^- + \bar{e} \rightarrow O^{2-}$ (endothermic)

$O + 2\bar{e} \rightarrow O^{2-}$ (endothermic)

$\Delta_{eg}H$: $S > Se > Te > Po > O$

due to small size of oxygen & inter electron repulsion, O has least $\Delta_{eg}H$

Catenation

S can show catenation.

Chemical properties

Oxidation State

Elements Group 16 GEC: $ns^2 np^4$

max OS $= +6$

min OS $= -2$

stability of -2 oxidation state ↓ses down the group due to ↑sed atomic size & ↑sed metallic character.

stability : $O^{2-} > S^{2-}$

* except O, all other elements can show +2, +4 & +6 OS, ⇒ +4 & +6 are most common OS.

S, Se, Te ⇒ shows +4, +6 OS with O & F.

* Stability of +6 OS ↓ses & +4 OS ↑ses on going down the group due to inert pair effect.

Reaction with O_2

all elements (except O) can form oxides of the type EO_2 & EO_3

Both types of oxides are acidic in nature & on dissolving in water it forms oxy acids

$$SO_2 \xrightarrow{H_2O} H_2SO_3$$

$$SO_3 \xrightarrow{H_2O} H_2SO_4$$

Acidic nature : $SO_2 < SO_3$

* on going down the group Acidic nature of oxides ↓ses.

Reaction with Hydrogen

All elements of Group 16 forms hydrides of the type H_2E.

H_2O H_2S H_2Se H_2Te.

⇓

It has extensive H bond

1 $H_2\ddot{O}$: can form 4 H bond

$H_2O \Rightarrow$ Liquid H_2S, H_2Se, H_2Te $\Rightarrow$ Gases.

MP/BP : $H_2S < H_2Se < H_2Te < H_2O$

Highest.

ΔH_f: (KJ/mol)	H_2O	H_2S	H_2Se	H_2Te.
	-286	-20	73	100

$\underbrace{-286 \quad -20}_{\text{exothermic.}} \quad \underbrace{73 \quad 100}_{\text{endothermic}}$

Bond length in H_2E : $H_2O < H_2S < H_2Se < H_2Te$.

Bond angle : $H_2O > H_2S > H_2Se > H_2Te$

104.5 ⇓ sp3 Hybridised

$\underbrace{92 \quad 91 \quad 90.}_{\text{Not undergone Hybridisation.}}$

* thermal stability ↓ses down the group

$H_2O > H_2S > H_2Se > H_2Te$.

* Reducing nature

Reducing nature of Hydrides ↑ses down the group.

$H_2\overset{-2}{O} < H_2\overset{-2}{S} < H_2Se < H_2Te$.

It can only undergo oxidation

* Reaction with Halogens

elements of Group 16 (except O) can form a number of halide EX_6 EX_4 EX_2 [X = F, Cl, Br, I]

* O forms O_2F_2 & OF_2

stability order: $F^- > Cl^- > Br^- > I^-$.

* Among hexa halides, hexa fluorides are stable
  SF_6, SeF_6 & TeF_6 stable. (sp^3d^2 - octahedral)
  $\Downarrow$
  exceptionally stable.

* tetra fluorides $\Downarrow$ $sp^3d \Rightarrow$ see saw.

  SF_4 $\Downarrow$ Gas, SeF_4 liquid, TeF_4 Gas.

$$Se_2Cl_2 \longrightarrow SeCl_4 + Se.$$