NON-METALS

NOBLE GASES

1. *Fill the table below on the basis of the following text.*

	Compounds	Occurrence	Uses	Special properties
Helium				
Neon				
Argon				
Krypton				
Xenon				
Radon				

Noble gases are elements from the group 18 (VII. A) from the periodic table. They were discovered in 1895 by W. Ramsay. He isolated them by fractional distillation of liquid air (Ne, Kr, Xe). Radon was isolated in 1902 by Rutherford and Soddy. Helium was discovered slightly earlier in the spectrum of the Sun. (1868)

The general electronic configuration of noble gases is ns^2 np^6 (an exception: He: $1s^2$). As they have a full shell they are unreactive.Until 1962 they were thought to be absolutely unreactive. The first compounds prepared were fluorides of xenon and krypton.

Helium was discovered in 1868. Helium forms 25% of the matter of the universe as it is made by nuclear fusion in stars. On the Earth it is present in natural gas. It is the second lightest element at normal conditions and so it is used in balloons and airships where it replaced the lighter but more dangerous hydrogen. Helium is also used in discharge tubes where it produces an orange-red glow. Liquid helium is used in cryogenics (for production of low temperatures). Helium below -270°C behaves as a superfluid which means that it can run out of any vessel which is not sealed.

Superfluid helium: http://www.youtube.com/watch?v=2Z6UJbwxBZI&feature=related

Neon is very rare on the Earth. Traces of it may be found in the air. It is used in discharge tubes where it produces a red colour. It is used for advertising signs.

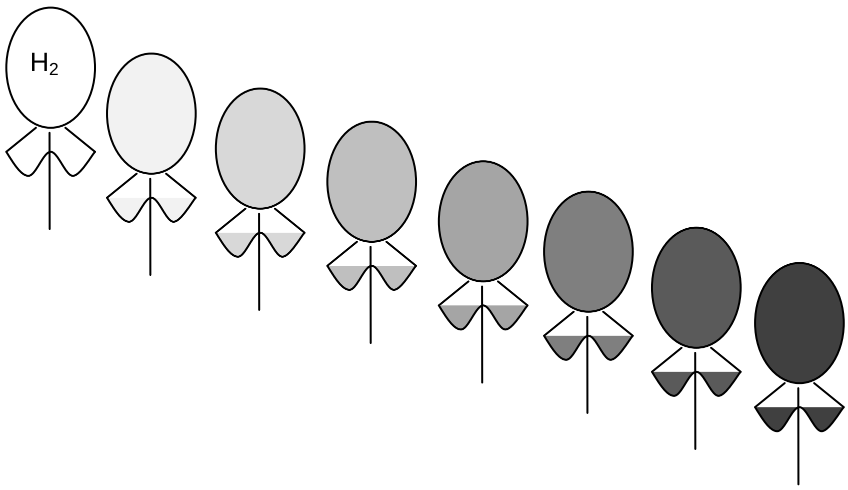
Argon is one of the most abundant noble gases on the Earth. It forms less than 1% of the atmosphere and it is a byproduct of the manufacture of O_2 and N_2. It is quite cheap and due to its inertness (unreactivity) it has many uses. It is used as a protective atmosphere in welding, fill gas in light bulbs, windows. In fire extinguishers it is used in such cases where damage to the equipment has to be avoided. Argon, like all the other noble gases is used in discharge tubes where it glows in a pink colour.

Traces of krypton are found in the air. Krypton together with argon is used in energy saving fluorescent lamps and light bulbs. In discharge tubes it glows white. Colourfully painted glass tubes filled with krypton are used for advertising signs.

Xenon is used in lasers and the radioactivity of Kr -133 is used in medicine for imaging heart, lungs and brain and for measuring the blood flow.

Radon is an element produced in the ground by the decay of radium. It is present in hot springs and in crude oil. It is emitted from the ground and it may penetrate into buildings. If the house is not air-conditioned sufficiently radon cumulates in the building and when inhaled it causes lung cancer because it is radioactive. It is the second major cause of lung cancer. The use of radon is very limited because the half-life of its most stable isotope Rn-222 is very short (3.824 days). It is used in medicine (cancer treatment).

2. *Try to explain why it is easier to make fluorides of xenon than that of argon. Why is it unlikely to prepare fluorides of helium and neon?*
3. *Put the noble gases in order with respect of increasing boiling points.*
4. *Why cannot light bulbs be filled with air?*
5. *Fill the symbols of noble gases and air into the balloons.*



6. *What is the principal cause of lung cancer?*

7. *Suggest the ways to protect yourself from the exposure to radon.*

8. *Match the names of noble gases with their meanings:*

INACTIVE	HELIUM
NEW	NEON
HIDDEN	ARGON
RADIATION	KRYPTON
STRANGER	XENON
SUN	RADON

9. *Fluorides of noble gases are prepared by direct synthesis and the final product may be affected by the ratio between the amounts of the elements, by temperature and pressure. Write down the equations for the production of xenon difluoride and xenon hexafluoride.*

10. *Xenon trioxide may be made by the hydrolysis of its fluoride. Write down the equation of this hydrolysis, knowing that the other products are xenon, oxygen and hydrofluoric acid.*

11. *Why are noble gases so unreactive?*

GROUP VII – THE HALOGENS

Properties of halogens: http://www.youtube.com/watch?v=u2ogMUDBaf4

1. *Fill in the following table*

Halogen	Symbol	El. configuration	Ox. Numbers	Colour	State	Structure
Fluorine			−I			
	Cl		−I, I, III, V, VII			
		[Ar] $3d^{10}$ $4s^2$ $4p^5$			Liquid	
				Dark grey		I_2 molecules

2. *Explain the difference in oxidation numbers of fluorine and the rest of the halogens.*

3. *Explain why the boiling points of halogens increase going down the group.*

4. *Draw the box diagram for Cl_2.*

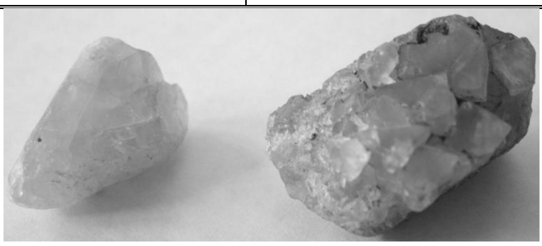
Halogens are typical non-metals, poisonous, irritant, pungent and corrosive.

Occurrence:

Halogens are so *reactive/unreactive* that they *never/allways* occur free. They occur naturally in compounds with metals.

Minerals:

CaF_2		
	Cryolite	Sodium hexafluoroaluminate
NaCl		
KCl		
$KCl \cdot MgCl_2 \cdot 6H_2O$	Carnallite	
$NaIO_3$	component of Salitre ($NaNO_3$ + KNO_3)	



Many halides are ……....………. in water, their ions are present in mineral ………… or in ……. water. Iodine is also present in seaweeds and it is important for the proper function of a .... gland. Chlorine in the form of hydrochloric acid is a component of gastric juice.

Chemical properties

The halogens are the most electronegative elements, they are very reactive, strong ……………… agents, the electronegativities and oxidising abilities ……………. going down the group, because of …………..……………… ……………………… …………..

1. reactions with non-metals → *ionic/molecular* halides

   $Cl_2 + S \rightarrow$

   $H_2 + X_2 \rightarrow$ ………….. halides

2. reactions with metals → ……...…...…. or .... halides

   $Na + Cl_2 \rightarrow$

   $Fe + Cl_2 \rightarrow$

3. Displacement reactions: A halogen with a …………… atomic number (………. electronegative) displaces a halogen with a ………… atomic number (……….. electronegative) from its halide.

   $Cl_2 + NaBr \rightarrow$

4. Disproportionation reactions with water or hydroxides:

   $Cl_2 + H_2O \rightarrow$

   $Cl_2 + 2\ NaOH \rightarrow$

5. Halogenation: substitution or addition reactions in organic chemistry

   $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

   5. *Explain why the oxidising abilities decrease going down the group.*
   6. *Explain what happens when chlorine gas is bubbled through:*
      a. *aqueous potassium iodide*
      b. *aqueous potassium bromide*
      c. *aqueous potassium fluoride*
   7. *Chlorine is regarded as an oxidising agent*
      a. *Explain this statement in the terms of electron transfer.*
      b. *Discuss the reaction of chlorine with: i) Br^-(aq) ii) Sn^{2+}(aq)*
   8. *Decide which of the following reactions take(s) place:*
      a. $I_2 + NaBr \rightarrow$
      b. $F_2 + KBr \rightarrow$
      c. $Br_2 + NaCl \rightarrow$

Obtaining halogens

Is based on *oxidation/reduction* of halides

$2\ X^{-}$ ………. → X_2^{0}

1. electrolysis of halides

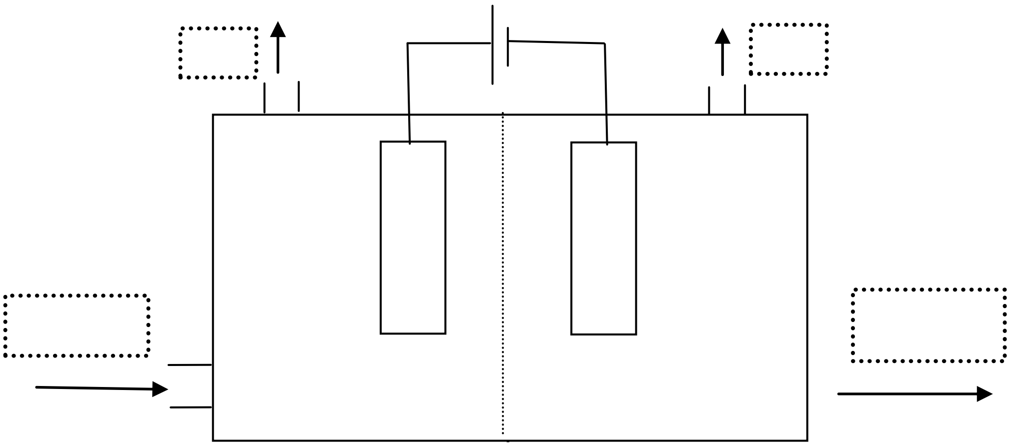
   Manufacture of chlorine: chlorine is manufactured by electrolysis of brine (solanka) = NaCl solution

   At the graphite anode: Cl^{-} ……….. → 1/2 Cl_2

   At the cathode: Na^{+} ……… → Na   Na + H_2O →

   The anode and the cathode are separated by a membrane permeable for sodium ions only.

   9. Suggest why the cathode and the anode must be separated.



2. oxidation of halides using oxidation agents (MnO_2, $KMnO_4$,…)

   10. Balance this equation

   $KMnO_4$ + HCl → Cl_2 + KCl + $MnCl_2$ + H_2O

3. displacement halide reactions

   Br_2 + 2KI →

   11. Explain why chlorine gas can be prepared from chlorides by "chemical" methods but fluorine gas has to be prepared by electrolysis.

Uses:

fluorine:

chlorine:

bromine:

iodine:

12. *Correct the mistakes in the following text:*
Halogens are: chlorine, oxygen, bromine and hydrogen. Chlorine is a colourless gas with a pungent smell. It is not toxic and it is used as a bleaching agent and as a disinfectant. It occurs in the atmosphere together with oxygen and nitrogen and it forms diatomic molecules.

13. *Chlorinated water is made by dissolving 0.1 mg of chlorine per 1 dm^3 of water. Calculate the mass percentage of chlorine in chlorinated water.*

Periodic table of videos: iodine: http://www.youtube.com/watch?v=ARXSnu8ImqQ

Halogen song: http://www.youtube.com/watch?v=qvs4ntb71uy&feature=related

Compounds of halogens

Halogens form various substances with other elements the more readily the further they are from each other in the periodic table.

Halides:

1. **hydrogen halides**

HF, ….., ….., ….. = irritating, pungent gases, they dissolve in ………. to form ………., their strength *increases/decreases* from HF to HI.

HF has much *higher/lower* boiling point than other hydrogen halides and hydrofluoric acid is a *weak/strong* acid while the others are *strong/weak* ones. This is caused by ……..........…….. ……………. between hydrogen fluoride molecules. HF is used for the decoration of glass as it is able to ………. it. That is why it must be stored in ....bottles.
http://www.youtube.com/watch?v=Nz8skbYjUlQ

HCl is used in .... removers. and it is contained in a .... juice.

2. **metal and non-metal halides**

- anionic: ionic bonding – ionic crystals
  with metals from the Group I and II
- covalent: covalent bonding between atoms – giant covalent structures
  with metals from the center of the periodic table
- molecular: simple molecules, ……..........................……….. forces between them
  with non-metals and metalloids

14. *Classify the following halides according to their structure: KCl, PCl_3, CCl_4, $TiBr_4$, VCl_5, NaCl, $SnCl_4$, CaF_2, PCl_5, $TiCl_4$, SCl_4, $MgCl_2$.*

How a metal halide may be made during a chemical reaction:

1. direct synthesis $Ca + Cl_2 \rightarrow CaCl_2$
2. acid + metal $HCl + Ca \rightarrow CaCl_2 + H_2$
3. acid + metal oxide HCl + ….. → $CaCl_2$ +
4. acid + metal hydroxide HCl + …….. → $CaCl_2$ +
5. acid + metal carbonate HCl + ……… → $CaCl_2$ +

15. Write 5 equations for the formation of sodium bromide.

3. interhalogens

The halogen with *lower/higher* electronegativity oxidises the halogen with lower electronegativity.

ClF chlorine monofluoride, colourless gas

ClF_3 chlorine ………………..., colourless gas

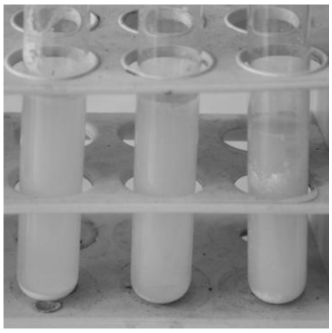
IF_7 ……………… ………………., colourless gas

BrF_3 ...., green liquid

They are very reactive volatile substances.

Testing for the presence of halide ions:

16. Match the silver halides with their colours:



$Cl^- + Ag^+ \rightarrow AgCl\downarrow$	Yellow
$Br^- + Ag^+ \rightarrow AgBr\downarrow$	White
$I^- + Ag^+ \rightarrow AgI\downarrow$	Yellowish

17. Suggest a soluble silver compound which may be used for the above reactions.

Important halides:

KI_3 – Lugol's solution ($KI + I_2$) used in analytical chemistry, + starch → .... colour
KI – analytical chemistry, iodised salt
AgBr – photography

Oxocompounds of halogens

Oxides: unstable. The most stable is I_2O_5.
Fluorine has *higher/lower* electronegativity than oxygen and that's why it has +/− oxidation number in their compound.

18. *Suggest the formula and the name of the binary compound of oxygen and fluorine.*

Oxoacids:

All halogens except fluorine form oxoacids.Their common oxidation numbers there are **…, …, …, ….** As the oxidation number of the halogen increases acid strength *decreases/increases*, thermal stability *decreases/increases* and oxidation power *decreases/increases*.

19. *Write the molecular and structural formulae for:*

chloric (I) acid

chloric (III) acid

chloric (V) acid

chloric (VII) acid

20. *Explain why the strengths of the chloric acids increase as the number of oxygen atoms in the molecule increases.*
21. *Put HClO, HBrO and HIO in order with respect of increasing strength.*
22. *Explain why chlorine, bromine and iodine form halic (V) acid, whereas fluorine cannot.*

Salts of oxoacids:

NaClO sodium ……………………, component of SAVO due to its ……………….. and ……………….. properties.

$Ca(ClO)_2$ ...., bleaching powder, disinfectant

$NaClO_2$ sodium ……………………

$NaClO_3$ sodium ……………………, herbicide

$KClO_3$ ...., laboratory preparation of oxygen, explosives

$KClO_4$ potassium ……………………, used in fireworks

<u>*Questions:*</u>

1. *Explain why the pH of an aqueous solution of NaF is greater than* 7 *while that of NaCl is* 7.

2. *Describe the observations which can be noted in each of the following experiments and write equations:*
   a. *Potassium permanganate (manganate(VII)) crystals are mixed with concentrated hydrochloric acid.*
   b. *Aqueous potassium chloride and aqueous silver nitrate are mixed.*
   c. *Aqueous bromine is mixed with potassium iodide solution.*
3. *If potassium chlorate(V) is heated above its melting point, oxygen is evolved as the only gaseous product and the residue contains no oxygen.*
   a. *Write the equation for this reaction.*
   b. *Write the change in oxidation numbers, if any, for potassium, chlorine and oxygen.*
   c. *Describe briefly a simple test tube experiment to confirm the nature of the anion present in the residue.*
4. *If potassium chlorate(V) is heated to its melting point, a reaction in which no oxygen is evolved occurs according to the equation:* $4KClO_3 \rightarrow KCl + 3KClO_4$
   a. *What is the oxidation number of chlorine in* Cl^- *and in* ClO_4^-*.*
   b. *What type of a reaction does this illustrate? Give a reason for your answer.*
   c. *Name the oxosalt in the product and give an equation for its thermal decomposition.*
5. *From your knowledge of the halogens, predict what happens in the following situations. Write equations for any reactions that take place. (Ignore the radioactive nature of astatine.)*
   a. *Astatine vapour is mixed with hydrogen at 100°C.*
   b. *Astatine is added to aqueous sodium hydroxide.*
   c. *Aqueous silver nitrate is added to aqueous sodium astatide.*
6. *Name the compounds A to H in the diagram.*

$$NaCl(aq) + H_2O(l) + CO_2 \xleftarrow{\textbf{D}} \textbf{C} \xleftarrow{water} \textbf{HCl(g)} \xrightarrow{NH_3(g)} \textbf{A} \xrightarrow{NaOH(aq)} NaCl(aq) + H_2O(l) + \textbf{B}$$

$$\textbf{C} \;\downarrow Zn(s)$$

$$\textbf{E} + \textbf{F} \xrightarrow[AgNO_3(aq)]{} \textbf{G} + \textbf{H}$$

7. *Make the names or formulae for:*

NaClO	*chloric(VII) acid*
H_5IO_6	*iodine monobromide*
$TiCl_4$	*magnesium iodate(V)*

HBr *sodium bromate(III)*

KIO *calcium fluoride*

SULPHUR S

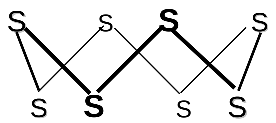
1. *Write down the **electronic configuration** of sulphur.*
2. *Write down the box diagrams for the valence electrons of sulphur in its:*

   a. *Ground state* S:
   b. *First excited state* S^*:
   c. *Second excited state* S^{**}:

3. The most common **oxidation numbers** of sulphur are: ...., ..., ...
   a. *Explain it with the help of the box diagrams above.*
   b. *Give an example of a sulphur compound for each of these oxidation numbers.*

Allotropes of sulphur

	Shape of crystals		Structure	Stability
Rhombic	*Short/long*	*Fat/thin*	S_8	*More/less* stable
Monoclinic	*Short/long*	*Fat/thin*	S_8	*More/less* stable

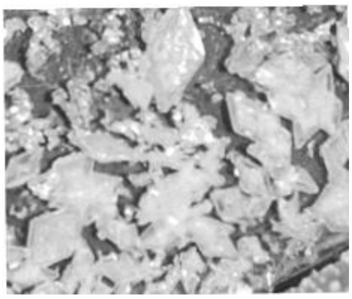


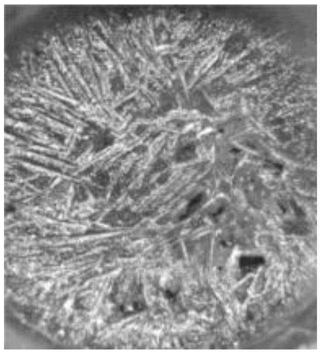
4. *Why is not the S_8 molecule planar but crown like?*

Both rhombic and monoclinic sulphur has *high/low* density, *high/low* melting point and it is soluble in *water/CS_2*.

5. *Give a reason for the above properties.*
6. *What is the name of CS_2?*

Plastic sulphur = dark rubbery mass consisting of sulphur .... of various lenghts S_x. It may be prepared by cooling .... sulphur in ....



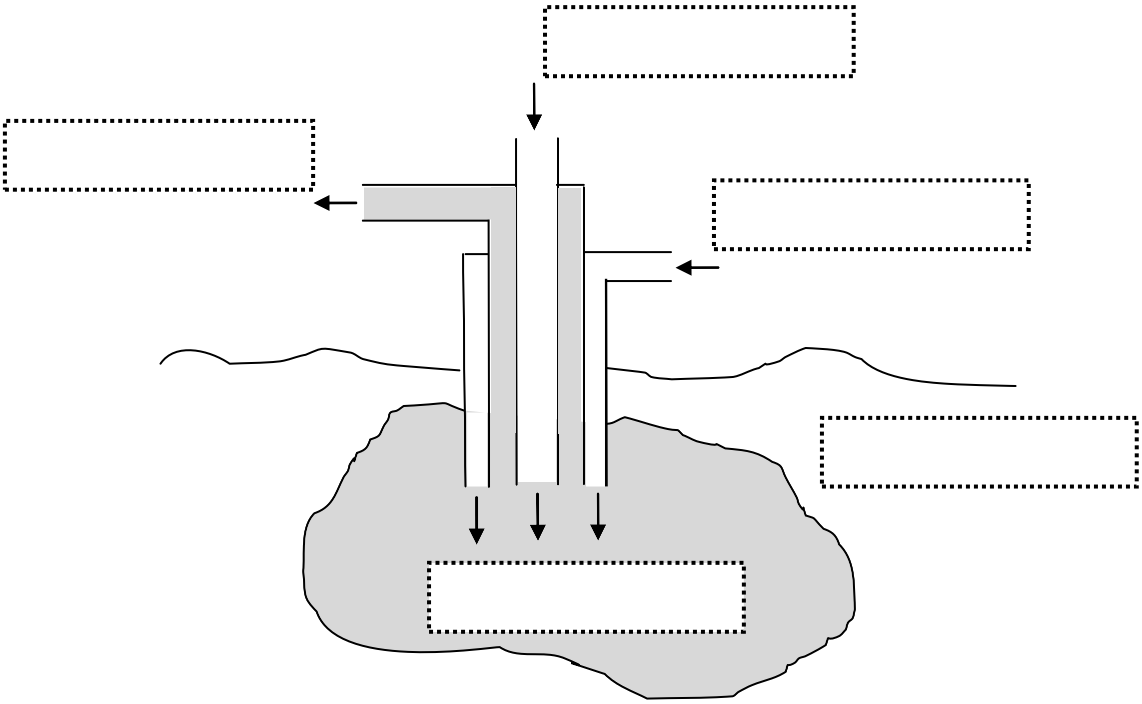


7. *Match the allotropes of sulphur with their pictures.*

Occurence

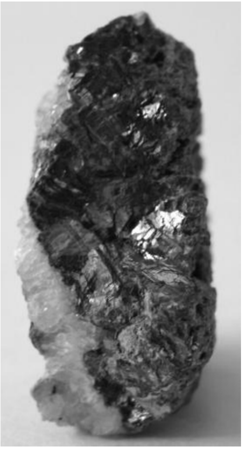
<u>Free:</u> Mexico, USA – obtaining by Frash process: Superheated water is pumped down into the deposit and melts the sulphur. Compressed air is pumped down a concentric pipe at the same time and a frothy mixture is pushed to the surface.

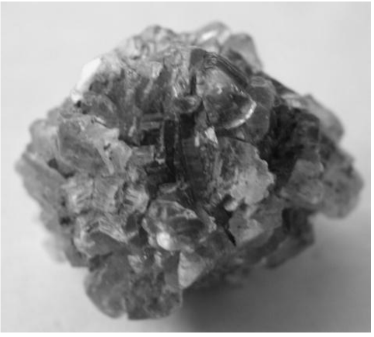
8. *Fill the following labels into the picture of Frasch process:SULPHUR DEPOSIT, ROCK LAYERS, MOLTEN SULPHUR, SUPERHEATED WATER, HOT COMPRESSED AIR*

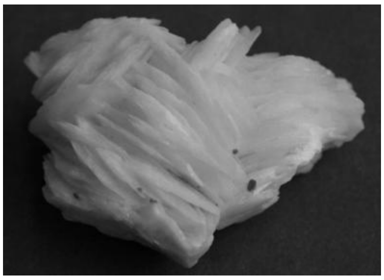


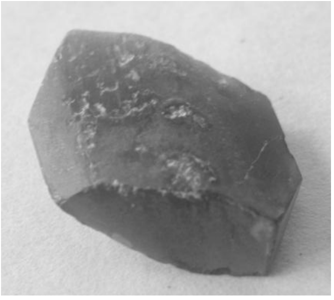
In compounds - sulphides or sulphates:

PbS	Galena		$CaSO_4$	Anhydrite	
ZnS	Zinc blende		$CaSO_4 \cdot 2H_2O$	Gypsum	
FeS_2	Pyrite	Iron (II) disulphide	$BaSO_4$	Barite	
H_2S			$CuSO_4 \cdot 5H_2O$	Blue vitrol	









Chemical properties

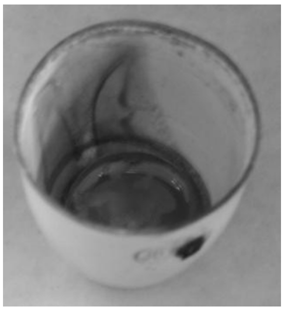
At high temperature sulphur reacts with most elements:

$S + O_2 \rightarrow$ sulphur burns with a .... flame

$S + H_2 \rightarrow$

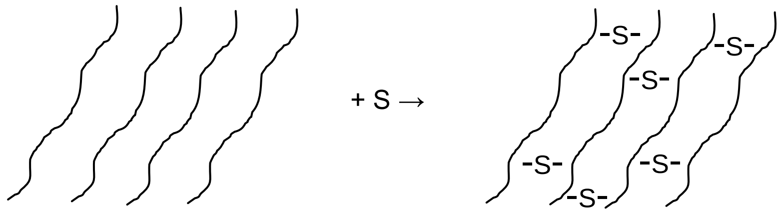
S + metals → ....,

S acts as an *oxidising/reducing* agent: Zn + S →



Uses of sulphur

- Manufacture of .... acid
- Vulcanization of rubber – sulphur is used to form cross-links between the rubber molecules.



The chains of natural rubber hold together due to .... forces. After the vulcanization they hold together by .... bonds which are much *weaker/stronger*. The vulcanized rubber is *softer/harder*. Such rubber is used e.g. in car ....

<u>Sulphides</u>

H_2S: ....

= a toxic gas with a disgusting smell reminiscent of ...., it dissolves readily in water to form a weakly *acidic/basic* solution.

Preparation: displacing from sulphides: FeS + HCl →

Reactions: H_2S reacts as a *strong/weak* diprotic acid forming hydrogen sulphides and sulphides

$H_2S(aq) + H_2O(l) \leftrightarrow$

$HS^-(aq) + H_2O(l) \leftrightarrow$

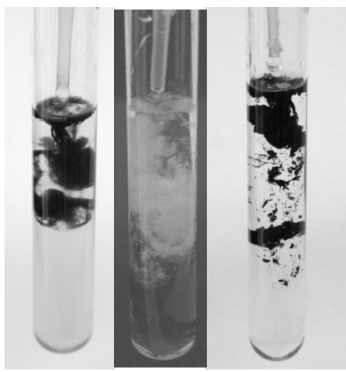
Metal sulphides

May be prepared by:

- direct synthesis from the elements: Fe + S →
- precipitation reactions (most sulphides are insoluble in water)

  $CuSO_4(aq) + H_2S(aq) \rightarrow$

  $Cu^{2+} + S^{2-} \rightarrow$ black precipitate



9. *Write down two equations for the preparation of:*
   a. *ZnS*

   b. *PbS*

<u>Oxocompounds</u>

SO_2 sulphur dioxide

= colourless toxic gas with a choking smell.

SO_2 is made when sulphur burns in oxygen or air: $S + O_2 \rightarrow$

SO_2 is one of the major air pollutants. The main source of this pollution is burning fossil fuels.

10. *Show in the map of the mean concentrations of SO_2 in 1996 the following power plants: Tisová (Sokolov), Tušimice (Chomutov), Prunéřov (Chomutov), Dětmarovice (Karviná), Třebovice (Ostrava), Chvaletice (Pardubice), Ledvice (Teplice), Počerady (Louny), Mělník*

11. *Suggest a way how can sulphur get into the fossil fuels.*
12. *What are the other sources of SO_2 emissions except of the coal power plants?*

SO_2 in the atmosphere causes the diseases of the .... system.

It also contributes to .... rains because it reacts with water and oxygen:

$SO_2 + H_2O \rightarrow$

$SO_2 + O_2 + H_2O \rightarrow$

As an acidic oxide it reacts with bases to form salts: $SO_2 + NaOH \rightarrow$

It may be displaced from the salts by some stronger acid: $Na_2SO_3 + HCl \rightarrow$

Sulphur dioxide takes place not only in acid base reactions but also in redox reactions.

13. *Explain the fact that SO_2 acts both as an oxidising and a reducing agent on the basis of the following equations:*

$SO_2 + 2H_2S \rightarrow 3S + 2H_2O$ .... agent

$SO_2 + O_2 \rightarrow SO_3$ .... agent

Uses of SO_2:

- Wine-making – protection from ....
- Reducing bleach for bleaching ...., ..., and so on

14. *Explain why sulphites may act as reducing agents and balance the following equation:*

$Na_2SO_3 + KMnO_4 + H_2SO_4 \rightarrow K_2SO_4 + Na_2SO_4 + MnSO_4 + H_2O$

H_2SO_4 sulphuric acid

= strong diprotic acid, colourless, viscous liquid, concentrated is ....%, density: about .... heavier than water.

Chemical properties:

- acid: $H_2SO_4 + H_2O \leftrightarrow$ .... + ... = hydrogen sulphate ion
  $HSO_4^- + H_2O \leftrightarrow H_3O^+$ + ... ion
  = highly exothermic reaction, water can boil, that is why always add .... to .... and never the opposite way round.

  Reacts with metal oxides, hydroxides and salts of weak acids:

  $H_2SO_4 + MgO \rightarrow$

  $H_2SO_4 + NaOH \rightarrow$

  $H_2SO_4 + CaCO_3 \rightarrow$

- oxidising agent: dilute H_2SO_4 reacts with reactive metals liberating hydrogen:

  $H_2SO_4 + Fe \rightarrow$

  $H_2SO_4 + Zn \rightarrow$

  $H_2SO_4 + Al \rightarrow$

  concentrated H_2SO_4 is able to dissolve Cu but it does not react with Fe and Pb

  $H_2SO_4 + Cu \rightarrow$

- dehydrating agent: conc. H_2SO_4 extracts the elements of water from compounds

  sucrose $C_{12}H_{22}O_{11}(s) \xrightarrow{H2SO4}$

15. *H_2SO_4 acts as a dehydrating agent on e.g. HCOOH or H_3PO_4. Write balanced equations for these reactions.*

Production: contact process

1. $S + O_2 \rightarrow$
2. $SO_2 + ½O_2 \xrightarrow{V2O5}$ .... white solid reacting too vigorously with water
3. $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ = ... acid, mixture of H_2SO_4 a $H_2S_2O_7$ = ...
4. $H_2S_2O_7$ + ... $\rightarrow 2\ H_2SO_4$

Uses:

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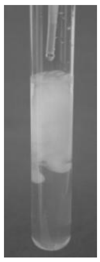


Evidence of SO_4^{2-}: $Ba^{2+} + SO_4^{2-} \rightarrow$ .... white↓

From the Czech Broadcast news: (quotation)

Two people were injured by an explosion in chemical factory in Prerov

Two people were burnt due to a hydrogen explosion which happened on Friday morning in the chemical factory Precheza in Prerov. The policemen say that the explosion happened when the employee were washing out a train tank which transported concentrated sulphuric acid. One of the two man was seriously injured and had to be transported to the centre of burns in Ostrava the second one was transported to the hospital in Prerov. „The men filled the tank with water and then they were pumping the water out through the upper lid of the tank to a special drain....“

16. *Write down the equation of the reaction which caused the explosion.*
17. *Guess what was the tank made from.*
18. *Write down the equation for the reaction between the metal of the tank and sulphuric acid.*
19. *Explain why such reaction did not take place during the transport.*

20. *10 ml of conc.* H_2SO_4 *(*$w = 96\%$*,* $\rho = 1.83\ g/cm^3$*) were diluted to 1litre. What is the pH of this solution? Describe the equipments and the procedure you would use for the dilution.*

21. *Determine the molecular formulae of two acids of sulphur knowing their compositions are as follows:*
    a. $w(H) = 1.75\%$, $w(S) = 56.14\%$, $w(O) = 42.11\%$
    b. $w(H) = 1.75\%$, $w(S) = 28.07\%$, $w(O) = 70.18\%$

22. *Give the names or the formulae for:*

calcium hydrogen sulphate(IV)	SO_3
sulphur hexafluoride	SF_4
sodium hydrogen sulphide	$K_2S_2O_7$
disulphuric acid	$ZnSO_4 \cdot 7H_2O$
sulphurous acid	K_2SO_3

23. *Finish the equations and name all the reactants and products:*
    a. $H_2SO_4 + NH_3 \rightarrow$
    b. $Na_2SO_3 + H_2SO_4 \rightarrow$
    c. $NaOH + SO_2 \rightarrow$
    d. $Al + S \rightarrow$
    e. $H_2SO_4 + Al_2O_3 \rightarrow$
    f. $ZnO + H_2SO_4 \rightarrow$
    g. $K_2S + H_2SO_4 \rightarrow$
    h. $H_2S + Cd(NO_3)_2 \rightarrow$

NITROGEN

1. *Find nitrogen in the periodic table, write down its electron configuration, use the box diagram to show its valence electrons and show the bonding between two nitrogen atoms.*

2. *List all the inorganic nitrogen species mentioned in the text about nitrogen in nature and fill the table below. What are the most often oxidation numbers of nitrogen?*

Name	Formula	Ox.n. of N

Name	Formula	Ox.n. of N

Nitrogen in the nature

Nitrogen is an important biogenous element, it is contained in substances important for life – proteins, aminoacids, nucleic acids, vitamins, hormones and enzymes.

Although it forms 78% of the atmosphere it cannot be used directly by organisms to form such compounds as it is highly unreactive. It must be „fixed“ first; this means it must be converted into a form that can be accepted by living organisms – into ammonia NH_3,ammonium ion NH_4^+ or nitrates NO_3^-.

There are two primary routes for nitrogen fixation:

Atmospheric fixation caused by lightning – nitrogen combines with oxygen in the presence of an electrical discharge. Nitrogen monoxide formed this way may be further oxidised by the atmospheric oxygen and nitrogen dioxide with water in the atmosphere form nitric acid which is neutralised by compounds in the soil to form nitrates.

Biological fixation is caused by the nitrogen fixing bacteria living on the root nodules of leguminuos plants (peas, beans, peanuts,...) in a symbiotic relationship with the plant. Leguminious plants are highly rich in proteins. When plant proteins are consumed by herbivores they convert them into animal proteins.

Excrement of animals and dead bodies of plants or animals decay with the help of bacteria. A part of the nitrogen stays in the soil in the form of ammonia or nitrates and it is used by other plants. A part of it turns to N_2 or N_2O which goes back into the atmosphere.

To increase the crops in fields the amount of nitrogen in the soil may be increased by artificial fertilizers – nitrogen substances soluble in water – ammonium nitrate, ammonium sulphate, sodium nitrate, potassium nitrate,...

Because of high solubility a large amount of fertilizers is washed by rains into underground water or into rivers or lakes. This fact has two unpleasant consequences:

An increased level of nitrates in drinking water causes cancer. Nitrates themseves are not dangerous but in the body they turn into nitrites (NO_2^-) and they form carcinogenic nitrosocompounds (organic compounds containing NO- group attached to carbon atom).

The second unpleasant fact is that an increased level of nitrates in lakes causes rapid growth of water plants like algae. When these plants die there is a high demand for oxygen for the decay of their bodies. When the oxygen from the water has been consumed the fish and other water animals have a lack of it and die. Such high level of nitrates and other nutrients is called eutrification of lake water.

3. *Fill in the missing words:*

Nitrogen is a ....(colour) and ....(odour) ....(state). It forms ....% of the volume of the atmosphere. It also occurs bonded in minerals like Chile saltpeter .... It is a biogenous element as it is contained in such substances like .... or DNA.
Nitrogen gas is manufactured by .... of ....

Nitrogen is unreactive due to a strong .... between nitrogen atoms. It forms ....* with reactive metals like Li or Mg. The oxidation number of nitrogen in ....* is ....Nitrogen reacts with H_2 at high ....and ....

and in the presence of .... to produce .... Nitrogen reacts also with oxygen at extremely .... temperatures e.g. in .... or ....

Nitrogen is used as an inert atmosphere due to its low .... e.g. in the food industry for .... packing. Liquid nitrogen is used for the production of low temperatures e.g. in medicine for cryoconservation of .... or ....or for cryotherapy, e.g. for removing .... Liquid nitrogen is also used in the food industry for ....food like meat or vegetables.

4. *Write down the equations for the reactions described in the text above.*

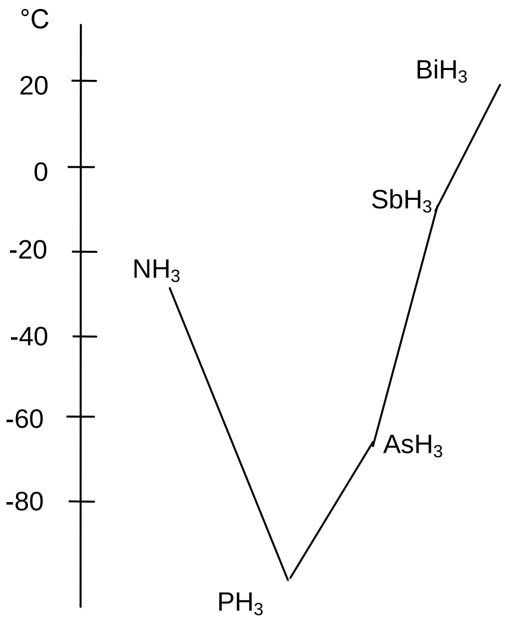
<u>Nitrogen compounds</u>

Ammonia NH_3

5. *Draw the box diagram for the NH_3 molecule. What is the shape of the NH_3 molecule? Is it polar or non-polar?*

6. *Fill in the blank or choose the correct words: „*Ammonia is *toxic/non-toxic ....(colour) .... (state).* It smells like *bad eggs/decaying urine."*

7. *See the graph below and explain the trends in boiling points of hydrides of elements from the Group V.*



8. *Draw a picture to show the hydrogen bonding between two molecules of ammonia.*

9. Ammonia is a weak base. *Support this statement by finishing the following equations*:

   a. $NH_3 + H_2O \rightarrow$

   b. $NH_3 + HCl \rightarrow$

   c. $NH_3 + H_2SO_4 \rightarrow$

   d. $NH_4Cl + NaOH \rightarrow$

10. *Name the products of the reactions above.*
11. *Draw the box diagram for NH_4^+. What kind of bonding is there between NH_3 and H^+?*

Ammonia is produced in a large scale from its elements by Haber-Bosch synthesis. This reaction takes place at high temperature and pressure in the presence of an iron catalyst.

12. *Use an equation to describe this process.*

Ammonia may be prepared in a laboratory by:

   a. thermal decomposition of ammonium chloride
   b. displacement reaction from ammonium salt and a strong alkali.

13. *Write down equations for both reactions.*

14. *Give two uses of ammonia.*

Hydrazine N_2H_4

15. *Suggest a structural formula of hydrazine.*

16. *Give one use of hydrazine.*

Nitrogen oxides

17. Fill the following table.

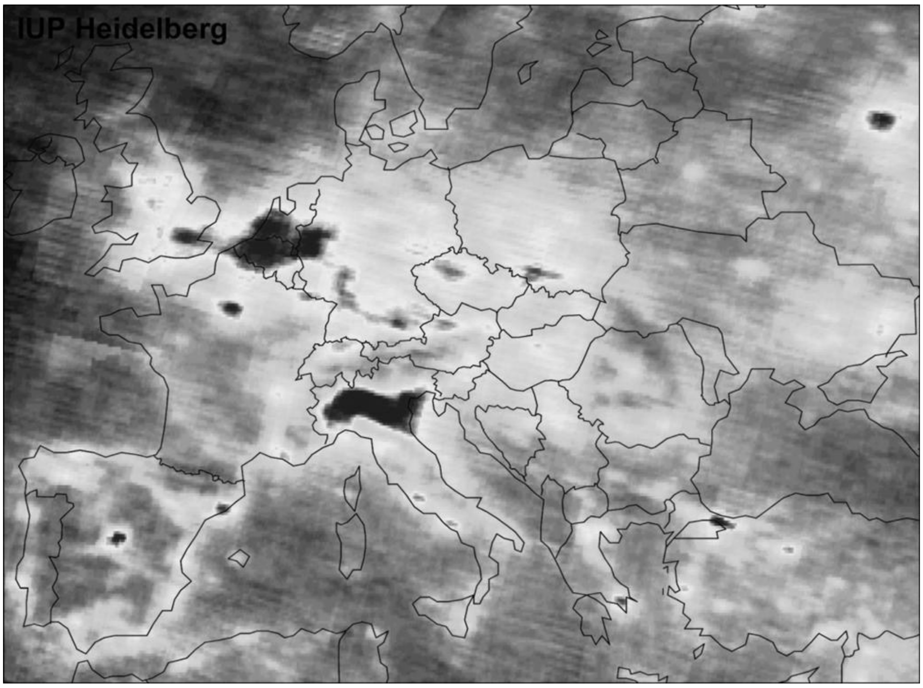
	Name	Colour	State	Use	Environmental problems
N_2O					
NO					
NO_2					

18. Describe the conditions at which nitrogen and oxygen combine to produce NO.

19. Finish equations:

a. $NO + O_2 \rightarrow$
b. $NO_2 + H_2O \rightarrow$

20. Use the picture of NO_2 pollution in Europe from January 2003 to June 2004 to detect the following cities: London, Paris, Madrid, Barcelona, Prague, Roma, Athens, Moscow.



21. *Explain the large dark stains in the map of Europe.*

Nitric (III) acid = nitrous acid

22. *Make the molecular and the structural formula of nitrous acid*

23. *Estimate the bonding angles of a. O-N-O bonds b. N-O-H bonds.*

24. *HW: Use the internet to find what substance has the E-number E 250. What is its English and Czech chemical name? State its use and the potential danger connected with this use.*

25. Nitrous acid is unstable and decomposes according to the following equation:

    $HNO_2 \rightarrow HNO_3 + NO + H_2O$

    What kind of redox reaction is this? Write down the half equations of oxidation and reduction. Balance this equation. What is the name of the salts of this acid?

Nitric acid

= strong monoprotic acid, toxic, corrosive, causes yellow stains on skin (evidence of proteins). In the presence of light it decomposes to nitrogen dioxide, oxygen and water. Ordinary concentrated nitric acid of commerce is 68%.

26. The manufacture of nitric acid has four steps. *Use their descriptions to write down the equations of these four reactions:*
    1. Haber-Bosch process
    2. Ammonia is oxidised by oxygen to nitrogen monoxide with the help of a platinum catalyst.
    3. Oxidation of nitrogen monoxide
    4. Reaction of nitrogen dioxide with water

Nitric acid undergoes three types of reactions. It acts as:

a. a strong acid

    $HNO_3 + NaOH \rightarrow$

    $HNO_3 + MgO \rightarrow$

b. <u>an oxidising agent</u> – most of metals do not displace hydrogen (only Mg, Mn and Ca displace H_2 from cold dilute acid), nitric acid is reduced to nitrogen oxides; HNO_3 is able to oxidise noble metals (except of Au, Pt, Rh)

27. *Balance equations:*

Cu + HNO_3 (conc. = 65%) → $Cu(NO_3)_2$ + NO_2 + H_2O

Cu + HNO_3 (50%) → $Cu(NO_3)_2$ + NO + H_2O

28. *Finish: Mn + HNO_3 (dil.) →*

Aqua regia = mixture HNO_3:HCl = 1:3, dissolves gold

c. <u>a nitrating agent</u>

HNO_3 is used for the production of trinitrotoluene.

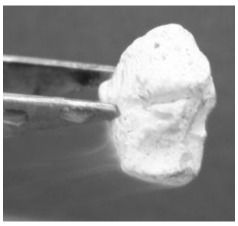
29. *What is the formula of toluene (methylbenzene)? What is the abbreviation of trinitrotoluene? What is its use?*

30. *Give four uses of nitric acid.*

31. *Explain why nitric acid is stronger than nitrous acid.*

<u>PHOSPHORUS</u>

1. *Find phosphorus in the periodic table, write down its electronic configuration and use the box diagram to show its valence electrons.*

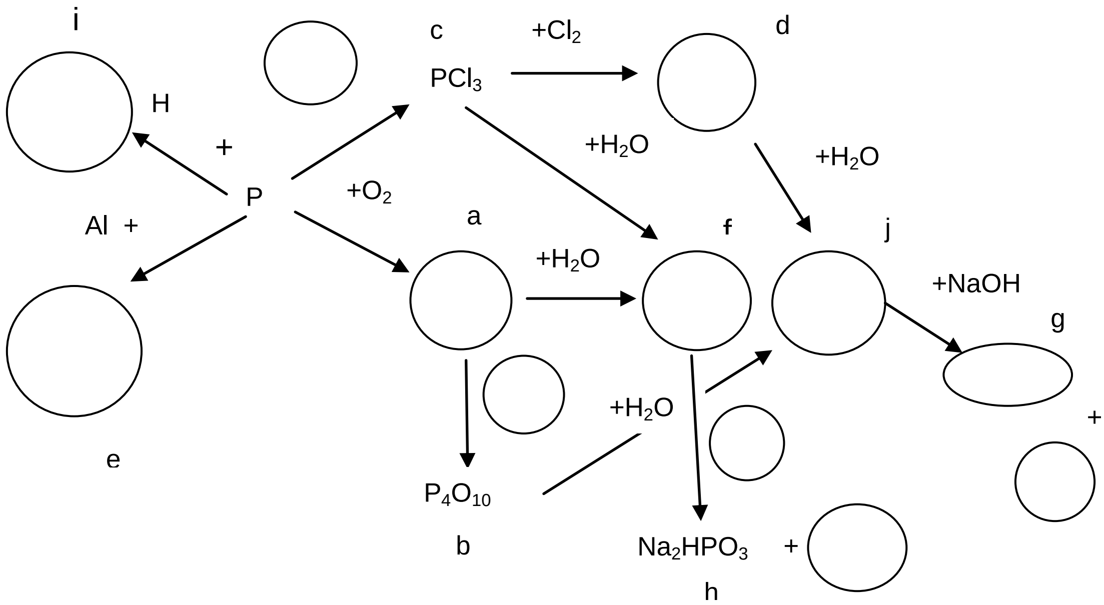
2. *Fill the table with allotropes of phosphorus.*

Name	Structure	Properties

3. *Draw the P_4 molecule knowing that phosphorus atoms are placed in the corners of a regular tetrahedron, calculate the bonding angles and explain its high reactivity.*

Phosphorus occurs in minerals like .... or in living organisms as a part of biologically important substances like ...., ..., ..., ..., ... or in the form of phosphates in .... or ....

4. *Fill in or choose the correct missing words or formulae:* „Phosphine .... (formula) is a *toxic/non-toxic*...................(state) that smells like .... Like ammonia it is a week *acid/base*. Its conjugate acid has the formula .... It is *more/less* soluble in water than ammonia because it *can/cannot* form hydrogen bonds with water molecules.“
5. *Fill in the missing formulae into the spider with the* <u>*reactions of phosphorus and its compounds*</u>*:*



6. *Name the substances a-e in the spider.*

7. *Match the substances f-j with the following names: phosphine, phosphoric acid, phosphorous (phosphonic) acid, sodium phosphate, sodium hydrogen phosphite*

8. *What is the appearance of phosphorus oxides? What does it mean that they are hygroscopic?*

9. *What is the appearance of phosphoric acid?*

10. *State three uses of phosphoric acid.*

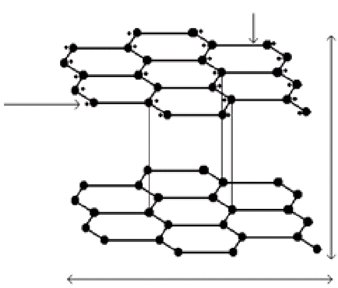
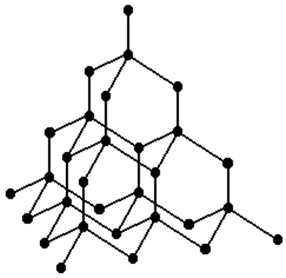
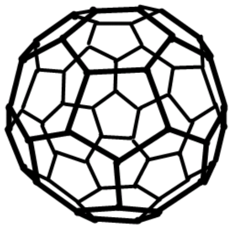
CARBON

1. *Write down the box diagram for carbon in:*

    a. Ground state: *C:* ☐ ☐☐☐

    b. Excited state: *C*:* ☐ ☐☐☐

2. *Describe the structures of the three natural allotropes of carbon:*

3. *Match the following properties and uses with diamond and graphite:*

1. **SOFT**
2. **OPAQUE**
3. **TRANSPARENT**
4. **SLIDING LAYERS**
5. **HARD**
6. **SHINY**
7. **EL. INSULATOR**
8. **THERMAL INSULATOR**
9. **EL. CONDUCTOR**
10. **THERMAL CONDUCTOR**


ELECTRODES
ABRASIVE
CUTTING TOOLS
JEWELLERY
LEAD IN PENCILS
LUBRICANTS
RODS IN NUCLEAR REACTORS

4. *State what properties make diamond and graphite suitable for the above uses.*

5. *Fill in the missing words in the following text about man-made forms of carbon, write down their Czech names in the brackets:* „If you heat wood in the absence of air you will get .... (.................................). It is often used for ....One of the products of distillation of coal is ....(..............). It is used as a .... agent for the production of ......, ..., ..., ..., ... Activated carbon (...........................) has high ...., it can ....

some substances to it. It is used in .... or in ....Unburnt fuel residues contain ....(..............). It is used in .... and as a ...., e.g. as ....




Chemical properties of carbon

Carbon reacts as a .... agent.

$C(s) + O_2(g) \xrightarrow{<1000K}$ (g)

$C(s) + O_2(g) \xrightarrow{>1000K}$ (g)

At higher temperature C reacts with other non-metals and steam:

$4C(s) + S_8(s) \rightarrow$

$C(s) + H_2O(g) \rightarrow$ = water gas - major source of ....

6. *Compare the* ***properties of carbon monoxide and carbon dioxide***:

	CO	CO_2
State		
Colour		
Odour		
Structure		
Solubility in water		
Acidity		
Toxicity		

7. *Explain the toxicity of CO*

8. *Give one use of CO_2*

9. *Explain the term* dry ice. *What is it used for?*

10. *State:*
   a. *biological importance:*
   b. *environmental problem connected with CO_2.*

Carbonates

11. Most carbonates are insoluble in water. Exceptions are: ammonium carbonate, sodium carbonate and potassium carbonate. *Write down their formulae*.

12. Existing hydrogen carbonates are: sodium hydrogen carbonate and potassium hydrogen carbonate. Calcium hydrogen carbonate and magnesium hydrogen carbonate are known in aqueous solutions only. *Write down their formulae*.

13. Reactions of carbonates and hydrogen carbonates

a. <u>Formation of stalactites</u>: *Write down the equations for the following processes:*
Water containing dissolved carbon dioxide is running through inorganic minerals like limestone and dissolves it.
Calcium hydrogen carbonate made in this water is unstable and as water vaporises it decomposes to form calcium carbonate, carbon dioxide and water again. The deposits of calcium carbonate are known as stalactites.

b. <u>Thermal decomposition of carbonates:</u> *Write down the equations for the following processes:*
Not only unstable hydrogen carbonates of calcium and magnesium decompose but also sodium and potassium hydrogen carbonates decompose when they are heated.

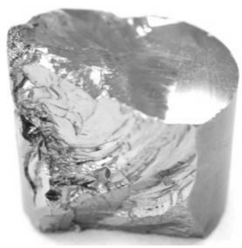
Thermal decomposition of limestone is used in the manufacture of ....

c. <u>Reactions with acids:</u> *Finish the following equations:*
$CaCO_3$ + HCl → HCl may be contained in some scale removers.
$NaHCO_3$ + HA (general formula of an acid) →
Effervescent tablets contain $NaHCO_3$ and citric acid, baking powder contains $NaHCO_3$ and some weak acid.

<u>SILICON</u>

1. What is its

a. electron configuration and the most common oxidation number



b. appearance

c. structure

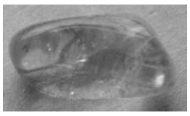
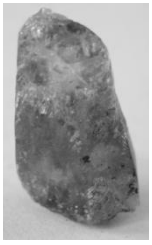
2. Name the silicon containing materials used in everyday life.

3. What is the raw material used for the production of silicon? How is silicon manufactured?

4. *Match the colours with the most common varietes of quartz SiO_2 (křemen):*

Citrine	**Pink**
Rose quartz	**Gold to red-brown**
Smoky quartz	**Brown to grey**
Tiger's eye	**Yellow**
Amethyst	**Purple**

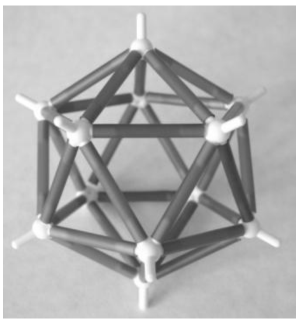



5. Explain the difference between physical properties of CO_2 and SiO_2 on the basis of their structures.

6. When sodium silicate is acidified it forms tetrahydrogensilicic acid......................................(eq) After dehydration ....(eq) it forms a type of silicon oxide known as .... It has high .... which is able to absorb .... readily. This is used to keep low relative humidity e.g. in .... to prevent them from spoiling. Such substances which are able to absorb water from the air are called .... SiO_2 in the form of sand is used in the mixture with slaked lime and water in the ....industry or to make ....*: SiO_2 is mixed with .... and .... and heated in a furnace to produce a gas of .... and a mixture of .... and .... which is ....*

7. What are silicon polymers and what are they used for?



BORON B

1. *Write down the box diagram for boron in its:*
   a. Ground state: *B:* ☐ ☐☐☐
   b. Excited state: *B*:* ☐ ☐☐☐

2. *What is the most common oxidation number of boron in its compounds?*
3. *Suggest two types of bond boron atoms take part in. (Hint: take on account the empty 2p orbital)*
    - .... bond
    - .... bond: boron acts as an electron pair ....

Boron has several allotropes, all of them are based on $B_{...........}$ icosahedra – they have .... corners and .... faces = regular .... Boron is dark, shiny, ... (state) metalloid. It *is/is not* very reactive. At *high/low* temperatures it takes part in the following reactions:

$B + O_2 \rightarrow$ .... **boron trioxide** = ... (colour, state), used for the production of .... stable borosilicate glass (laboratory equipment, ...)

$B + S \rightarrow$

$B + Cl_2 \rightarrow$

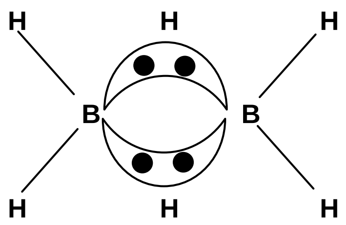
Boranes B_xH_y

They do not exist in nature, they are highly reactive

4. *What is the formula and the shape of the simplest borane?*

It is known in .... state only and it dimerises to diborane.

5. *Write down the equation for the dimerisation.*



3 center 2 electron bond (banana bond)

6. Borane is highly reactive, it reacts with Lewis bases, e.g. with ammonia it forms ammonia borane BH_3NH_3. *Use the box diagram to show the dative bond between BH_3 and NH_3.*

Boric acid H_3BO_3

= white crystalline solid, H_3BO_3 molecules hold together by ...., *weak/strong* acid, doesn't dissociate in water, Lewis acid, takes OH^- from water: $B(OH)_3 + OH^- \rightarrow$
Dilute H_3BO_3 solution = mild antiseptics used e.g. as an eyewash.

Sodium tetraborate $Na_2B_4O_7$

= mineral borax, source of boron, enamel glazes