CHEM 9.4.4 THE ATMOSPHERE

Human activity has caused changes in the composition and the structure of the atmosphere. Chemists monitor these changes so that further damage can be limited

4.1 Describe the **composition and layered structure** of the atmosphere

- Atmosphere: layer of gas surrounding earth, 200 – 300 km thick
- Composition: **78% Nitrogen, 21% Oxygen, 0.9% Argon**, and CO_2, Ne, He, CH_4, Kr, H, NO, CO, O_3
    - Water vapour ranges from 0.5% to 5% due to weather, etc
- Structure: divided into layers, **troposphere, stratosphere, mesosphere, thermosphere** (TSMT)
    - Troposphere – **0 to 15** km; temp **decreases** as altitude increases
        - Weather experienced here
    - Stratosphere – **15 to 50** km; temp **increases** as altitude increases – **ozone** layer here
    - Mesosphere and Thermosphere = ionosphere
    - **Tropopause, stratopause and mesopause** separate the four layers

4.2 Identify the **main pollutants** found in the **lower atmosphere** and their **sources**

- **Carbon monoxide** from cars, cigarettes, combustion stoves, fires
- **NO_x** from combustion (vehicles, power stations, factories)
- **Hydrocarbons** from vehicles, solvents
- **Particulates** from combustion, industrial processes, asbestos from insulation and buildings
- **VOCs** (volatile organic compounds) from commercial/domestic plants, homes, industrial
- **Airborne lead** from lead smelters, paint from old houses, leaded petrol

4.3 Describe **ozone** as a molecule able to act both as an **upper atmosphere UV radiation shield** and a **lower atmosphere pollutant**

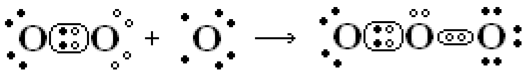
- Ozone: O_3, pale blue toxic gas, present in the **stratosphere and troposphere**
- In **stratosphere (upper atmosphere)** – ozone layer
    - Ozone blocks **UV-B and UV-C**, interacts with **O_2 and O_3**:
        - $O_{2\,(g)} + UV \rightarrow 2O\bullet_{(g)}$
        - $O_{3\,(g)} + UV \rightarrow O_{2\,(g)} + O\bullet_{(g)}$ (occurs more often as less energy required)
        - Oxygen radicals then react with O_2 or O_3 atoms, therefore absorbs UV light
- In **troposphere (lower atmosphere)** – atmosphere pollutant
    - **Poisonous** to humans – reacts with body tissue, causes **breathing and respiratory** issues
    - Produced by **photochemical smog** from NO_2 – air pollution from car exhaust gases
        - $NO_{2\,(g)} + UV \rightarrow NO_{(g)} + O\bullet_{(g)}$
        - The O• joins with oxygen to form ozone

4.4 Describe the formation of a **coordinate covalent bond**

- Covalent bonding: two atoms **share electrons** for a full shell
- Co-ordinate covalent bond: one atom **donates a pair of electrons**, both atoms **share the electrons**
  - Both atoms will result in a full shell
  - E.g. in **ozone**, see below

4.5 Demonstrate the **formation of coordinate covalent bonds** using **Lewis electron dot structures**

- Co-ordinate covalent bonds when **one atom donates a pair of electrons**
- For example, **ozone** forms a **coordinate covalent bond** and a **covalent bond**



- All oxygen atoms have **6 electrons initially**
  - Centre oxygen atom **donates a pair of electrons** and shares with the third oxygen atom
- For example, **CO** has a **coordinate covalent bond** and a **double covalent bond**

4.6 Compare the **properties of the oxygen allotropes O_2 and O_3** and account for them on the basis of **molecular structure and bonding**

- <u>Allotropes</u>: **different forms** of the **same element** with different physical properties

Property	**Oxygen (O_2)**	**Ozone (O_3)**
Colour, Odour	Colourless, odourless	Pale blue, strong odour
Boiling Point	**-183°C** Lower molecular mass – less energy	**-111°C**
Solubility in Water	**Low solubility** – non polar, weak intermolecular forces in polar water	**More soluble** – bent structure allows more intermolecular forces
Stability	Very stable $O_{2\,(g)} \rightarrow 2O\bullet_{(g)}\ \Delta H = \mathbf{498\ kJ/mol}$	Quite stable; easily decomposed to O_2 $O_{3\,(g)} \rightarrow O_{2\,(g)} + O\bullet_{(g)}\ \Delta H = \mathbf{106\ kJ/mol}$
Reactivity	Reacts to form **oxides** **Moderately strong** oxidising agent	Much more reactive **Very strong** oxidising agent – weak bond releases O• which can oxidise compound

4.7 Compare the **properties** of the **gaseous forms of oxygen** and the **oxygen free radical**

- <u>Free radical</u>: natural species with an **unpaired electron**
  - Formed by splitting molecule into 2 **neutral** fragments, **not ions**
- Oxygen radical – **two unpaired electrons** – **highly reactive**
  - Due to presence of **unpaired electrons** and **incomplete** valence shell
- Much more reactive than O_2, cannot be compared with BP or colour

4.8 Identify the **origins** of **chlorofluorocarbons (CFCs)** and **halons** in the atmosphere

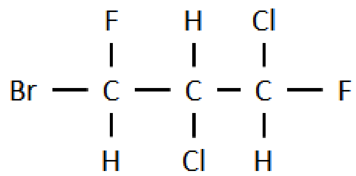
CHLOROFLUOROCARBONS

- <u>Chlorofluorocarbons</u>: compounds containing **chlorine, fluorine and carbon only**
- Replacements for **ammonia in refrigeration**, 1930s
- Properties: **BP** and dependence on **pressure** for frfridegs
  - **Odourless, non-flammable, non-toxic, inert**, unlike ammonia (toxic, odour)
- Uses: **refrigerants, air conditioners, propellants in aerosol spray cans, foaming/cleaning agents**
- **Released in atmosphere**, but were **inert and insoluble** – CFCs spread throughout air
  - Began diffusing into stratosphere

HALONS

- <u>Halons</u>: compounds containing **carbon, bromine and other halogens**
- Properties: **dense, non-flammable**
- Uses: **fire extinguishers** (**BCF** fire-extinguishers) in cars and boats
- Released **directly** in atmosphere, diffusing into stratosphere

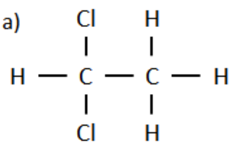
4.9 Identify and name **examples of isomers** (excluding geometrical and optical) **of haloalkanes** up to eight carbon atoms



- Use **IUPAC** nomenclature for naming haloalkanes, example (right):
  1. Carbon atoms: 3 = **propane**
  2. Halogen atoms (bromo-, chloro-, fluoro-, iodo-) in alphabetical order, add prefixes, number C location from most halogens (left or right)*
     a. If both ways have the **same amount from both directions**, start from more electronegative halogens (F > Cl > Br > I)
        = **3-<u>b</u>romo-1,2-di<u>c</u>hloro- 1,3-di<u>f</u>luoro-** (as Cl is more electronegative than Br)
  3. Join alkane and halogens together = **3-bromo-1,2-dichloro-1,3-difluoropropane**

- <u>Isomers</u>: compounds with **same chemical formula**, different **structural formula**
  - E.g. Draw all possible isomers of $C_2H_4Cl_2$ and name them:

a) 1,1-dichloroethane
b) 1,2-dichloroethane

a)


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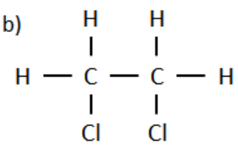

4.10 Discuss the **problems** associated with the **use of CFCs** and assess the **effectiveness** of steps taken to alleviate these problems

- Main problem – **destruction of ozone in the stratosphere** (ozone layer)
  1. Chlorofluorocarbons in contact with **UV radiation**: $CCl_3F_{(g)} + UV \rightarrow \boldsymbol{Cl\bullet_{(g)}} + CCl_2F\bullet_{(g)}$
  2. Chlorine radical reacts with ozone: $Cl\bullet_{(g)} + O_{3\,(g)} \rightarrow ClO\bullet_{(g)} + O_{2\,(g)}$
  3. Chlorine monoxide radical reacts with an O radical: $ClO\bullet_{(g)} + O\bullet_{(g)} \rightarrow Cl\bullet_{(g)} + O_{2\,(g)}$
  4. Chlorine is **regenerated** and can attack another O_3 molecule (**chain reaction**)
- Can be **removed by** $Cl\bullet_{(g)} + \boldsymbol{CH_{4\,(g)}} \rightarrow HCl_{(g)} + CH_3\bullet_{(g)}$ OR $ClO\bullet_{(g)} + \boldsymbol{NO_{2\,(g)}} \rightarrow ClONO_{2\,(g)}$
- Solutions: Montreal Protocol – international treaty to protect ozone layer
  - Ban manufacture and use of CFCs by **1996**, end halon use **1994**, phasing out HCFCs
- **Effectiveness**: quite **significant progress** – countries meeting required targets
  - No technology to remove CFCs, replacements not as effective

4.11 Analyse the information available that indicates **changes in atmospheric ozone concentrations**, describe the **changes observed** and explain how this **information was obtained**

- Total amount of ozone measured since **1957**
    - Main depletion of ozone **occurring over the Antarctic**
    - Ozone amount declines from 1970s, around **30% ozone depleted by 1985**
        - Not very dramatic now, though sometimes exceeding 50%
- Measurements taken **on the ground, balloons and satellites**
    - **Ground** – UV spectrophotometers, pointed up to measure **light intensity** for different wavelengths
    - **Balloon** – placed in high-altitude weather balloons, pointing downwards from above stratosphere
    - **Satellite** - TOMS (total ozone mapping spectrophotometers), scans entire earth