CHEM 9.3.2 ACIDIC OXIDES

While we usually think of the air around us as neutral, the atmosphere naturally contains acidic oxides of carbon, nitrogen and sulfur. The concentrations of these acidic oxides have been increasing since the Industrial Revolution

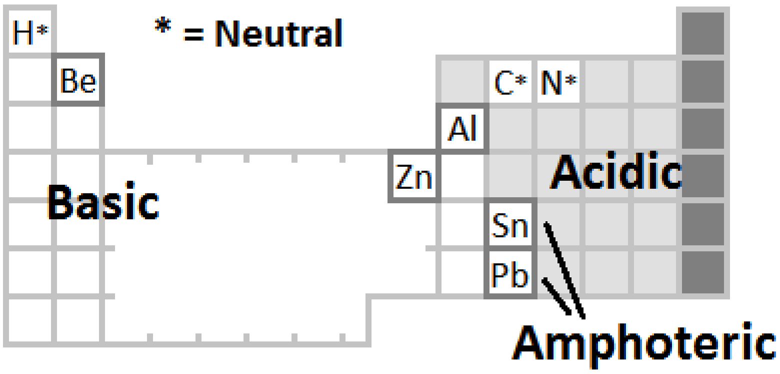
2.1 Identify **oxides of non-metals** which act as **acids** and describe the **conditions** under which they act as acids

- **Acidic oxide** formed by non-metals
  - Reacts with **water** to form an acid, reacts w/ base to form salts
  - Acidic oxide + water → acid

    $CO_{2\,(g)} + H_2O_{\,(l)} \rightarrow H_2CO_{3\,(aq)}$ (carbonic acid)
- **Basic oxide** formed by metals
  - Reacts with **water** to form bases, reacts w/ acid to form salts
- **Amphoteric oxides** react with both acids and bases
- **Neutral oxides** do not react with either

Acidic	Basic	Amphoteric	Neutral
SO_3	MgO	ZnO	CO
NO_2	CuO	Al_2O_3	NO
P_2O_5	Fe_2O_3	PbO	N_2O
SO_2	CaO	SnO	

2.2 Analyse the **position of these non-metals** in the Periodic Table and outline the **relationship** between **position** of elements in the Periodic Table and **acidity/basicity of oxides**



- **Basic** forms **ionic** compounds, **acidic** forms **covalent** compounds
- **Inert** gases **rarely form oxides**, XeO_3 was created

2.3 Define **Le Chatelier's principle**

- 1885, Le Chatelier:
  - The **concentration** of reactants and products in a mixture at equilibrium will **alter to counteract change** in **concentration, pressure** or **temperature**

2.4 Identify **factors** which can **affect the equilibrium** in a reversible reaction

- For an equilibrium, $\mathbf{A + B \rightleftharpoons C + D}$:
- Change in **concentration**
  - When A is increased **equilibrium shifts to the right** to reduce A+B concentration
- Change in **pressure**
  - If A is a gas, then increased pressure will shift **equilibrium to the right** to reduce pressure
- Change in **temperature**
  - If reaction is exothermic ($A + B \rightleftharpoons C + D + heat$), then equilibrium will shift **to the left** to reduce heat
- Adding a **catalyst** will only speed up the movement to equilibrium, will not shift

2.5 Describe the **solubility of carbon dioxide** in water under various conditions as an **equilibrium process** and explain in terms of **Le Chatelier's principle**

- Carbon dioxide reacts with water to form **carbonic acid** and ionises:

$$\mathbf{CO_{2\,(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3\,(sq)}(+heat)} \rightleftharpoons 2H^+_{(aq)} + CO_{3\,(aq)}^{2-}$$

- For first equilibrium:
  - Increase in **H_2O** **(concentration)** causes equilibrium to shift to the right
  - Increase in **pressure** will affect CO_2 (the only gas), meaning it will shift to the right
  - Since reaction is exothermic, increasing **temperature** will make equilibrium shift to the left
- For second equilibrium:
  - If NaOH is added, then $OH^-_{(aq)} + H^+_{(aq)} \rightarrow H_2O_{(l)}$ occurs and it shifts to right as H^+ is removed

2.6 Identify **natural** and **industrial sources** of sulfur dioxide and oxides of nitrogen

- Sulfur dioxide (SO_2)
  - Naturally from **geothermal hot springs** and **volcanoes**
  - Industrially from **burning** and **processing fossil fuels** and from **extracting metals**
- NO_x (**nitrous oxide** N_2O, **nitric oxide** NO and **nitrogen dioxide** NO_2)
  - Naturally, NO and NO_2 from **lightning**, N_2O from **bacteria** on nitrogenous materials in soils
  - Industrially, NO and NO_2 from **combustion** of fossil fuels and N_2O from use of nitrogenous **fertiliser**

2.7 Describe, using equations, examples of **chemical reactions** which release **sulfur dioxide** and chemical reactions which release **oxides of nitrogen**

- **Sulfur** in compounds reacts with oxygen: $S_{(s)} + O_{2\,(g)} \rightarrow SO_{2\,(g)}$
- **Metal sulfides** to metal oxides: $2ZnS_{(s)} + 3O_{2\,(g)} \rightarrow 2ZnO_{(s)} + 2SO_{2\,(g)}$

- **Lightning** and **combustion** reacts common gases: $O_{2\,(g)} + N_{2\,(g)} \rightarrow 2NO_{(g)}$
- NO **reacts with oxygen** in air: $2NO_{(g)} + O_{2\,(g)} \rightarrow 2NO_{2\,(g)}$

2.8 Assess the **evidence** which indicates **increases** in **atmospheric concentration** of oxides of sulfur and nitrogen

- Evidence gathered from quantitative analysis of **Antarctic ice** core samples and observed **damage**
  - Increased **concentration of N_2O** (increase 15% in 150 years), unchanging SO_2, NO and NO_2
  - Increased **damage** to buildings, forests, aquatic organisms (increased acidity)
- Difficulties gathering evidence:
  - SO_2 and NO_x measured around **0.001 ppm**, unlike CO_2 (360 ppm)
  - **Instruments measuring low concentrations** only commercially available in **1970s**
  - SO_2 and NO_2 form sulfate and nitrate ions that are mostly **soluble in water** (unlike carbonates)

2.9 Calculate **volumes of gases given masses** of some substances in reactions, and calculate masses of substances given gaseous volumes, in **reactions involving gases** at 0°C and 100kPa or 25°C and 100kPa

- Use a **balanced equation** to work out **concentration or mass**
  - $\mathbf{moles} = \frac{\mathbf{mass}}{\mathbf{molar\ mass}}$ and $\mathbf{moles} = \frac{\mathbf{volume}}{\mathbf{molar\ volume}}$
  - Molar volume from Data Sheet (22.71 and 24.79 L/mol)
- Example: Calculate the volume of **carbon dioxide** released at 100kPa and 25°C by the reaction of **10.0 g of calcium carbonate** with HCl.

  $2\mathrm{HCl}_{(aq)} + \mathrm{CaCO}_{3\,(s)} \rightarrow \mathrm{CaCl}_{2\,(aq)} + \mathrm{CO}_{2\,(g)} + \mathrm{H_2O}_{(l)}$ – mole ratio HCl and CO_2 is 1:1

  Calcium carbonate molar mass = 100.09 g/mol

  $\mathrm{moles} = \frac{10}{100.09} = 0.09\ldots$

  Therefore volume $\mathrm{CO_2} = \mathrm{moles} \times \mathrm{molar\ volume} = 0.09\ldots \times 24.79 = \mathbf{2.48\ L}$

2.10 Explain the **formation** and **effects** of **acid rain**

- Acid rain – rain with **higher H^+ concentration** than normal (**pH under 5**)
- Acids present are **sulphuric** and **nitric**, if unpolluted (pH 5.5 – 6) **carbon dioxide** dissolved (carbonic acid)
- **Acidic oxides** form by dissolving into water (rain)
  - $SO_{2\,(g)} + H_2O_{(l)} \rightarrow H_2SO_{3\,(aq)}$ – sulfur dioxide with water forms sulfurous acid
  - $2H_2SO_{3\,(aq)} + O_{2\,(g)} \xrightarrow{catalyst} 2H_2SO_{4\,(aq)}$ – catalyst from impurities in air
  - Similarly, $2NO_{2\,(g)} + H_2O_{(l)} \rightarrow HNO_{2\,(aq)} + HNO_{3\,(aq)}$ – forming nitrous acid
  - $2HNO_{2\,(aq)} + O_{2\,(g)} \xrightarrow{catalyst} 2HNO_{3\,(aq)}$
- Effects of acid rain include:
  - **Fall in soil pH**, causing damage to vegetation (difficulty to absorb calcium or potassium)
    - **Damage to leaves** and pine forests as waxes are removed
  - **Buildings and statues** eroding, as carbonates (concrete, marble, limestone) readily react with acids
  - **Aquatic organisms** die as pH goes under 5