**Elemental and Environmental Chemistry Practice Test**

**1. Aluminium is a relatively active metal that is found as alumina (Al2O3), which is quite abundant in the earth's crust**

**a)** State the group and period of Aluminium

*group 3, period 3*

**b)** What is the charge of the aluminium ion found in alumina?

*+3*

**c)** Write the electronic configuration of the aluminium ion found in alumina

*1s2 2s2 2p6 (loses 3s2 3p1)*

**d)** Acid rain can leach aluminium ions out of the soil. Why would these ions be more harmful to plants than solid aluminium metal?

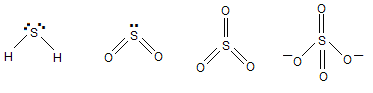
*Al3+ ions are water soluble. This means they are able to be taken up by plants through their roots. Solid aluminium cannot be taken in by plants and so are not directly harmful.*

**2.** **Sulfur can exist in numerous oxidation states**

**a)** State the oxidation number of sulfur in hydrogen sulfide, sulfur dioxide, sulfate and sulfur trioxide

*H2S = -2 SO2 = +4 SO3 = +6 SO42- = +6*

**b)** Draw and name the structure of these four oxides of sulfur, indicating any bonding and non- bonding pairs of electrons



*bent bent trigonal planar tetrahedral*

**c)** Explain what causes the hydrogen-sulfur bond to be polar

*Hydrogen and sulfur have different electronegativities. This causes the electrons in the bond to be unevenly shared, with the electrons being held closer to the sulfur atom (as the more electronegative element). This uneven sharing causes a slight negative charge on the sulfur atom. This slight difference in charges δ- for sulfur and δ+for hydrogen causes the bond to be polar.*

**d)** Explain whether the hydrogen sulfide molecule is polar or non-polar

*The hydrogen - sulfur bonds are slightly polar. The hydrogen sulfide molecule is bent, this means that it is asymmetrical. The combination of polar bonds and an asymmetrical molecule causes an overall imbalance of charge throughout the molecule, causing the molecule to be polar.*

**e)** Name one environmental concern that may be associated with the release of sulfur oxides

*Sulfur oxides are a major contributor to acid rain*

**f)** Hydrogen sulfide has a boiling point of -60oC, while water with a similar structure has a boiling point of 100oC, explain this difference of boiling points

*Difference in boiling points for molecular compounds is due to the difference in secondary interactions between the molecules. The stronger the secondary interactions, the higher the boiling point.*

*The difference in dispersion forces would be low, hydrogen sulfide will have slightly more due to the higher MW. Hydrogen sulfide is polar and so can form dipole-dipole bonds. The hydrogen - oxygen bond is much more polar than the hydrogen - sulfur bond and can form the stronger hydrogen bonds.*

*The difference in boiling points is due to water forming hydrogen bonds compared to the dipole-dipole bonds of hydrogen sulfide.*

**3.** **Nitrogen oxides are formed in high heat situations such as combustion engines and furnaces**

**a)** Why is atmospheric nitrogen only reactive at these high temperatures

*Atmospheric nitrogen forms extremely stable triple bonds. The activation energy required to break these bonds is very high. The temperatures required to overcome this activation energy is only found in these high temperatures.*

**b)** Write equations for the formation of nitrogen dioxide from atmospheric nitrogen and oxygen

*N2 + O2 → NO*

*2NO + O2 → 2NO2*

**c)** Write equations for the formation of ozone from nitrogen dioxide

*NO2 → NO + O*

*O + O2 → O3*

**d)** Account for the time differences for peak concentrations of nitrogen oxide, nitrogen dioxide and ozone

*Nitrogen oxide is formed directly from the air in high temperatures so its concentration peak occurs first. Nitrogen dioxide is formed from the reaction between nitrogen oxide and oxygen so its peak concentration occurs after the nitrogen oxide. Ozone can then be formed from the photochemical breakdown of nitrogen dioxide and is therefore the last peak to occur.*

**e)** Label these three compounds as primary or secondary pollutants

*Nitrogen oxide is primary, the other two are secondary*

**4.** **Sodium hypochlorite can be added to pools to purify the water**

**a)** Write an equation to show the formation of hypochlorous acid from hypochlorite ions

*OCl- + H2O → HOCl + OH-*

*base acid c. acid c. base*

**b)** Label the conjugate acid and base pairs from the previous equation

**c)** How could the equilibrium be manipulated to produce more hypochlorous acid

*Adding acid to react with the hydroxide ions would cause the equilibrium to re-establish itself to produce more of the hydroxide and hence the hypochlorous acid*

**5. Nitrogen is an important element in the growth of plants**

**a)** Explain, using equations, how atmospheric nitrogen can be made available for plants to use

*Making nitrogen available for use by plants is known as nitrogen fixation. It can occur via multiple pathways. Nitrogen fixing bacteria can convert atmospheric nitrogen into amino compounds. Lightning strikes can provide the activation energy for atmospheric nitrogen to react with oxygen.*

*N2 + O2 → NO*

*NO + O2 → NO2*

*This can then form nitrates including nitric and nitrous acids.*

*Ammonia can also be artificially created using the Haber process.*

*N2 + H2 → NH3*

**b)** Write the equation for respiration

*C6H12O6 + O2 → CO2 + H2O*

**6. Acid rain can be formed from sulfur and nitrogen oxides**

**a)** Calculate the minimum molar concentration of hydronium ions in acid rain

*minimum pH for acid rain is 5.6*

*[H3O+] = 10-5.6*

*[H3O+] = 2.51 x 10-6 mol L-1*

**b)** What are some problems caused by acid rain

*Acid rain can cause the degradation of marble and limestone buildings*

*CaCO3 + H+ → Ca2+ + CO2 + H2O*

*This causes the marble and limestone to dissolve.*

*It can also increase the oxidation of metal structures*

*Fe + H+ → Fe2+ + H2*

*Acid rain can also cause the leaching of metals into aqueous solutions which can cause problems for plants and aquatic life.*

**c)** *6H+ + Fe2O3 -> 2Fe3+ + 3H2O*

**7.** **Describe, using equations the difference between the reactions of metal and non-metal oxides with water, acids and bases**

*Metal oxides act as bases when dissolved in water*

*eg CaO + H2O → Ca2+ + 2OH-*

Note that you are highly unlikely to get a question as broad as this, I just want you to review each type of reaction

*Metal oxides can react with acid*

*eg CaO + H+ → Ca2+ + H2O*

*Non metal oxides act as acids when dissolved in water*

*eg CO2 + H2O → H2CO3*

*Non-metal oxides can react with bases*

*eg CO2 + OH- → CO32- + H2O*

**8.** **Many common compounds are molecular**

**a)** Describe the characteristics of a molecular compound

*non-metal compounds*

*relatively low melting and boiling points*

*do not conduct electricity*

**b)** What are the aerobic and anaerobic breakdown products of phosphorus

*aerobic = PO43- anaerobic = PH3*

phosphate phosphine

**c)** What is the oxidation number of phosphorus in these two compounds

*PO43- P -2x4 = -3 PH3 P + 3x1 = 0*

*P -8 = -3 P + 3 = 0*

*P = +5 P = -3*

**d)** Describe why phosphorus is able to have these two oxidation numbers (number and sign)

*Phosphorous is group 5 and so has 3 electrons needed to form a stable octet. It can gain these 3 electrons through bonding 3 times, leading to an oxidation number of 3.*

*Phosphorous being a period 3 element has an empty 3d shell. This allows phosphorous to use all of its valence shell electrons in bonds, as the d shell can accept the extra electrons past the normal octet. As phosphorous is in group 5 it has 5 valence electrons, so through expanding its octet it can form 5 bonds, for an oxidation number of 5.*

*Phosphorous will have a negative oxidation number when bonded to a more electronegative element such as oxygen.*

*Phosphorous will have a negative oxidation number when bonded to a less electronegative element such as hydrogen.*