

IB HL Chemistry
Option E: Environmental Chemistry



Student Workbook

IB HL Chemistry - Option E: Environmental Chemistry

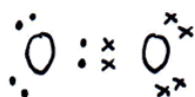
Instructions: Complete all questions in each section, using the references listed. You will need Internet access, Derry, et.al. *Chemistry Options: SL and HL* and this booklet to complete the topic.

1. http://en.wikibooks.org/wiki/IB_Chemistry/Environmental_Chemistry
2. http://www2.sd35.bc.ca/teachers/aklassen/klassens_Science_Page/IB_Chemistry_files/IB%20Chem%20environmental%20notes.pdf
3. <http://chemactive.com/ib.html>

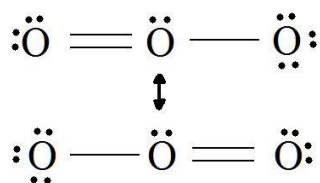
E9: Ozone Depletion

E.9.1 Explain the dependence of O₂ and O₃ dissociation on the wavelength of the Light.

1. Draw a Lewis dot diagram of diatomic oxygen



2. Draw a Lewis dot diagram of ozone



3. Define resonance structure.

Alternate forms of the same compound where there are delocalised electrons that allow alternate or resonant structures that are identical in 3-d space. In actuality, it is neither structure but an intermediate of the two (or more)

4. How many resonance hybrids does ozone have?

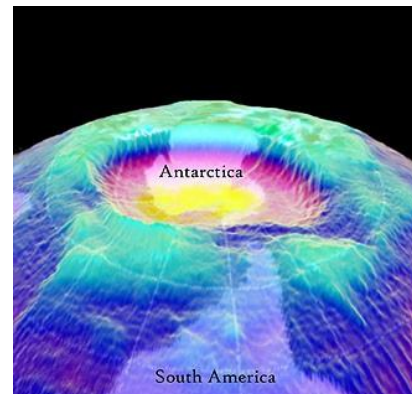
Two (see # 2 above)

5. How does the bond length of a resonance structure compare to the bond length of a single bond or a double bond?

It is one and half times (or half way between a single and a double bond)

6. How does the strength of the bonds in a diatomic oxygen molecule compare to the strength of the bonds in an ozone molecule.

Diatomic oxygen double bond is stronger than the 1 and half bond in ozone



Seasonal hole in the ozone layer over Antarctica Source: NASA

7. Which molecule requires more energy to dissociate, diatomic oxygen or ozone?

Diatomic oxygen

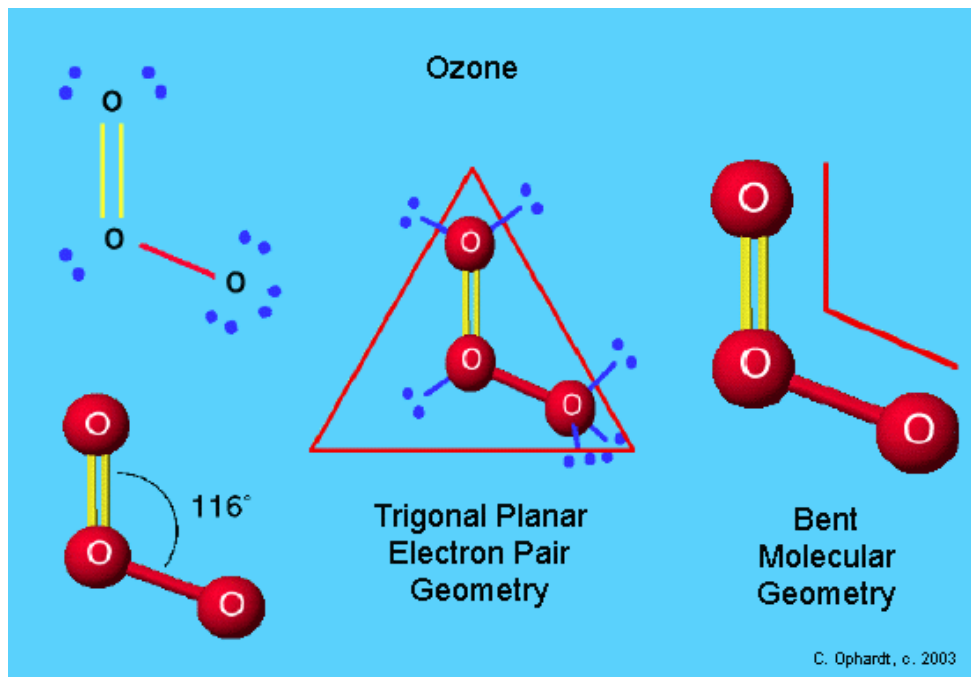
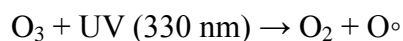
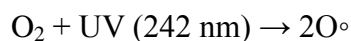
8. The wavelength of light to dissociate diatomic oxygen and ozone are 242 nm and 330 nm, respectively. In terms of frequency and energy, how do these two wavelengths compare to each other?

242 nm is a higher frequency and energy than 330 nm

9. Define free radical.

An atom or a molecule with at least one unpaired electron which are highly reactive

10. Write a balanced chemical equation for both the dissociation of oxygen and the dissociation of ozone. Make sure to represent the free radical correctly.

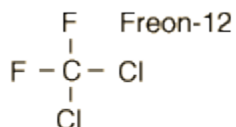


E.9.2 Describe the mechanism in the catalysis of O₃ depletion by CFC's and NO_x.

1. List some of the uses of chlorofluorocarbons.

- Refrigerants
- Propellants

2. Draw the Lewis dot diagram of a chlorofluorocarbon molecule.



Dichlorodifluoromethane

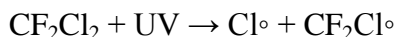
3. During ozone destruction which process produces chlorine radicals?

Decomposition of the CFC by uv light

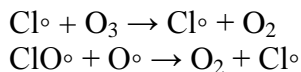
4. One molecule of CFC can catalyze up to 100,000 molecules of ozone.

5. Write equations to illustrate the catalysis of ozone destruction by CFC's. What makes it catalysis? (Refer to the syllabus)

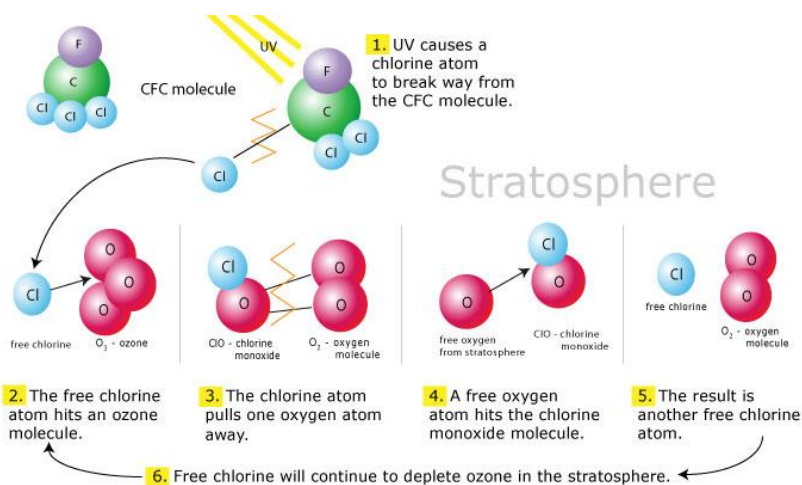
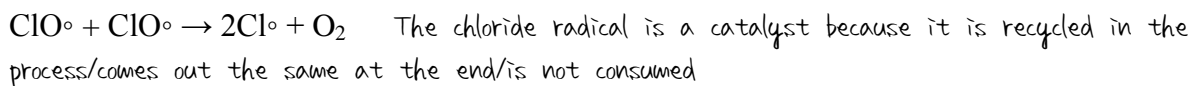
Initiation:



Propagation:

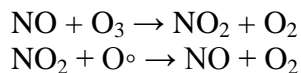


Termination:

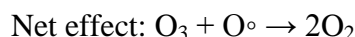


<http://www.dynamicscience.com.au/tester/solutions/chemistry/greenhouse/cfc.htm> shows an animation of the process if you would like a further visual

6. Outline the radical mechanism by which nitrogen oxides decompose ozone.



7. Write an equation demonstrating the net effect of the destruction of ozone?



E.9.3 Outline the reasons for greater ozone depletion in Polar Regions.

Reference: <http://www.atm.ch.cam.ac.uk/tour/part1.html>

There are several pages that give good explanations. Scroll to the bottom for the next page link.

1. Is Ozone the same everywhere? Explain.

Good ozone - found in the Stratosphere, protects us from harmful uv radiation

Bad ozone - found at ground level (Troposphere) as part of photochemical smog and is a health hazard

2. What substance acts as a surface catalyst?

The ice crystals found in Polar Stratospheric Clouds (PSCs) - the surface where chlorine (Cl₂) producing reactions occur

3. What factors make the spring season particularly bad for the ozone layer?

The ice crystals in PSCs melt and in combination with the increased uv radiation, release the Cl free-radicals which are then free to react with ozone

4. Ozone loss was first detected in the stratosphere over the Antarctic. Why is the Ozone Hole observed over Antarctica when CFC's are released mainly in the Northern Hemisphere?

Because PSCs are found in this region of the Earth's atmosphere. These are needed to concentrate the chlorine molecules that later form ozone destroying Cl free radicals

5. The graph below shows the measured total ozone above the Halley Bay station in Antarctica. Each point represents the average total ozone for the month of October. Suggest reasons for this dramatic fall of ozone.

The dramatic fall around 1975 is due to an increase in the 'halocarbons' which include CFCs

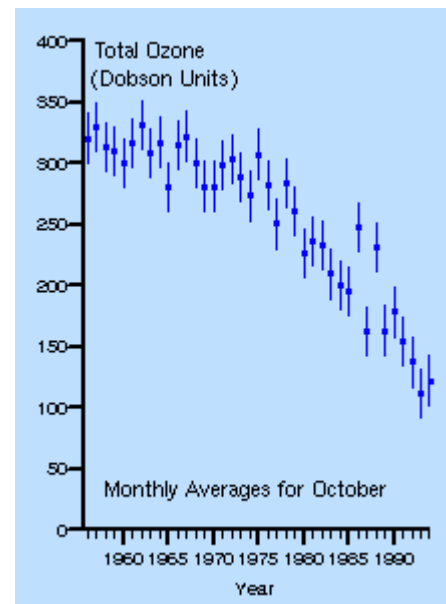


Figure 3: Ozone in Antarctica

6. Outline the 4 “ingredients” for the “Recipe for Ozone Loss” over Antarctica (Hint: see page III of the website referenced on the previous page)

- The polar winter leads to the formation of the polar vortex which isolates the air within it.
- Cold temperatures form inside the vortex; cold enough for the formation of Polar Stratospheric Clouds (PSCs). As the vortex air is isolated, the cold temperatures and the PSCs persist.
- Once the PSCs form, heterogeneous reactions take place and convert the inactive chlorine and bromine reservoirs to more active forms of chlorine and bromine.
- No ozone loss occurs until sunlight returns to the air inside the polar vortex and allows the production of active chlorine and initiates the catalytic ozone destruction cycles. Ozone loss is rapid. The ozone hole currently covers a geographic region a little bigger than Antarctica and extends nearly 10km in altitude in the lower stratosphere.

(from: <http://www.atm.ch.cam.ac.uk/tour/part3.html>)

E.10 Smog

E.10.1 State the source of primary pollutants and the conditions necessary for the formation of photochemical smog. Reference: <http://daphne.palomar.edu/calenvironment/smog.htm> - also see further links at the bottom of this web page.

1. Define smog.

The term smog comes from a combination of smoke and fog and was coined in 19th century London to describe the atmospheric combination of coal smoke and fog. Today it is more commonly used to describe photochemical smog which is the brown haze that is a mixture of pollutants that is brought about by reactions with uv radiation from the sun and is observed over many major cities on the planet.

2. What is the source of the primary pollutants of photochemical smog?

mostly from automobile exhaust and industrial power plant emissions

3. The two primary pollutants are VOCs and NO_x, especially NO.

4. List the 3 main conditions necessary for the formation of photochemical smog.

- NO_x
- VOCs
- uv radiation from the sun

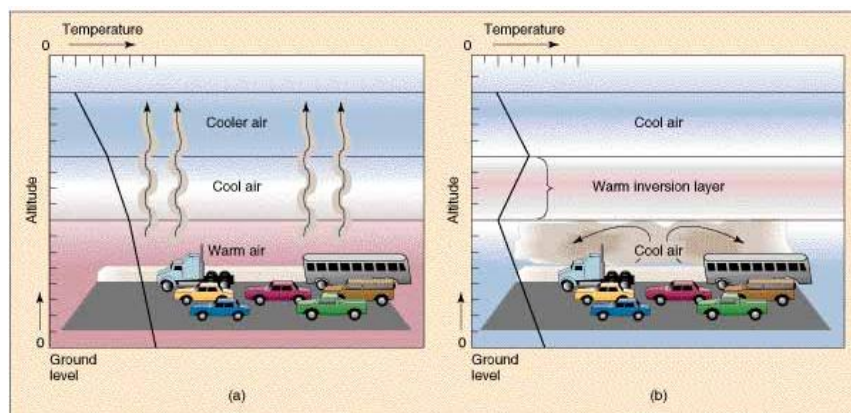
5. Smog is most likely to occur when there is ultraviolet radiation.

6. Describe the formation of thermal inversions.

Normally, temperature decreases as you increase altitude. A thermal inversion occurs when cold air is near the ground and there is a layer of warmer air above it. Since the cold air is denser than the warmer air above it, the air does not rise and pollutants get trapped.

7. Why does smog tend to become increasingly dangerous when there are thermal inversions?

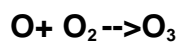
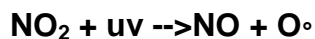
Because pollutants are trapped, they tend to accumulate near the surface of the Earth which leads to poor air quality.



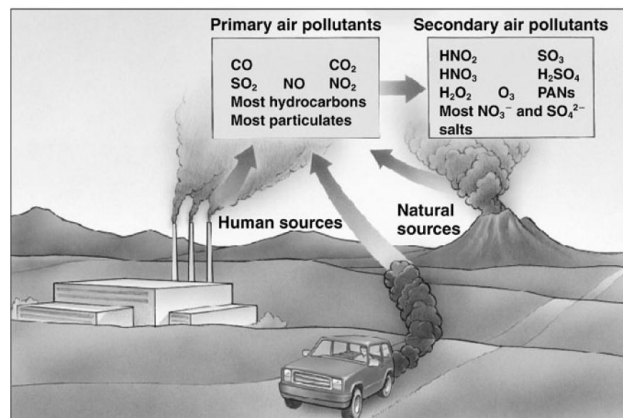
E.10.2 Outline the formation of secondary pollutants in photochemical smog. Treatment should be restricted to the formation of free radicals from the reaction of nitrogen oxides with sunlight and the reaction the these radicals with hydrocarbons, leading to the information of aldehydes and peroxyacnitrates (PANs)

1. What role does sunlight play in the formation of secondary pollutants in photochemical smog?

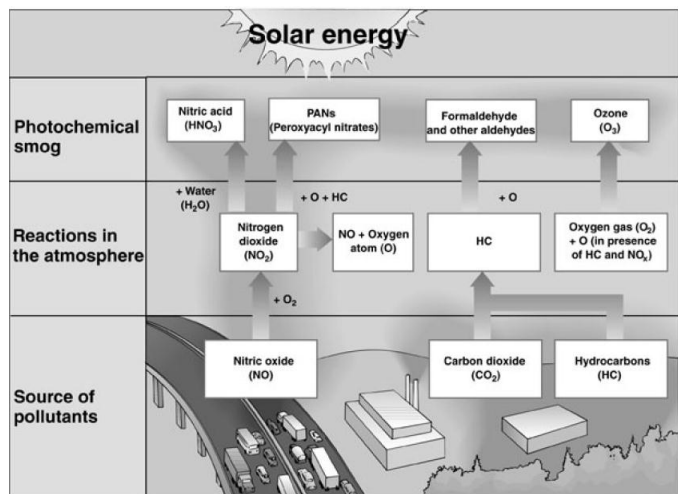
Sunlight provides the energy for the following reactions:



In the equilibrium reaction below, more sunlight shifts the reaction to the left producing more ozone



2. Draw a flow diagram outlining the daily, cyclical pattern of photochemical smog formation. Include all primary pollutants, secondary pollutants and catalysts.



Primary pollutants released by cars and industry:

- VOCs
- NOx (mostly NO)
- particulates

These other radicals can form peroxide radicals that form peroxyacetyl nitrates (PAN):

$$\text{RCH}_2^\bullet + \text{O}_2 \rightarrow \text{RCH}_2\text{OO}^\bullet \text{ (peroxy free radical \#1)}$$

$$\text{RCH}_2\text{OO}^\bullet + \text{NO}^\bullet \rightarrow \text{RCH}_2\text{O}^\bullet + \text{NO}_2$$

$$\text{RCH}_2\text{O}^\bullet + \text{O}_2 \rightarrow \text{RCHO} + \text{OH}_2^\bullet \text{ (aldehyde, RCHO)}$$

$$\text{RCHO} + \text{OH}^\bullet \rightarrow \text{RCO}^\bullet + \text{H}_2\text{O}$$

$$\text{RCO}^\bullet + \text{O}_2 \rightarrow \text{RCOOO}^\bullet \text{ (peroxy free radical \#2)}$$

$$\text{RCOOO}^\bullet + \text{NO}^\bullet \rightarrow \text{PAN (serious health effects)}$$

Primary pollutants react to form secondary pollutants in the air:

$$2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$$

$$\text{NO} + \text{O}_3 \rightleftharpoons \text{NO}_2 + \text{O}_2$$

UV radiation dissociates nitrogen dioxide:

$$2\text{NO}_2 + \text{uv} \rightarrow \text{NO} + \text{O}^\bullet$$

Oxygen free radicals initiate rxns producing ozone and hydroxyl radicals:

$$\text{O}^\bullet + \text{O}_2 \rightarrow \text{O}_3$$

$$\text{O}^\bullet + \text{H}_2\text{O} \rightarrow 2 \text{OH}^\bullet$$

Hydroxyl free radicals initiate rxns producing nitric acid and other radicals from hydrocarbons (RH):

$$\text{OH}^\bullet + \text{NO}_2 \rightarrow \text{HNO}_3$$

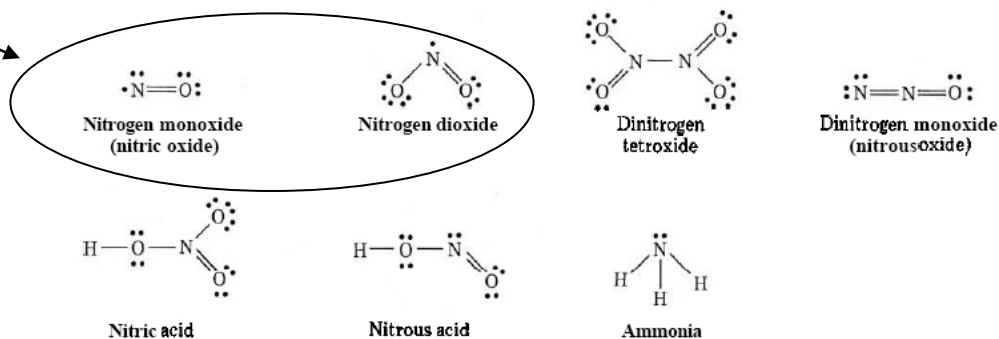
$$\text{OH}^\bullet + \text{RCH}_3 \rightarrow \text{RCH}_2^\bullet + \text{H}_2\text{O}$$

E11 Acid Deposition

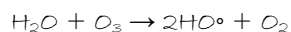
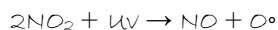
E.11.1 Describe the mechanism of acid deposition caused by the oxides of nitrogen and oxides of sulfur.

1. Draw the Lewis dot diagram for BOTH of the main oxides of nitrogen.

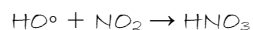
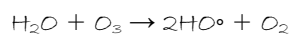
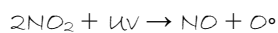
Main NO_x
cpds



2. Write the equations involved in the mechanism (series of reactions) for nitrous acid formation.



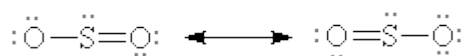
3. Write the equations involved in the mechanism (series of reactions) for nitric acid formation.



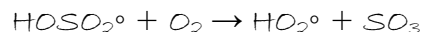
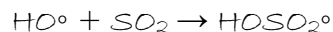
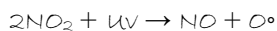
4. Which of the above acids is considered a strong acid?



5. Draw the Lewis dot diagram for sulfur dioxide.



6. Write the equations involved in the mechanism (series of reactions) for sulfuric acid formation.



7. All of the above mechanisms have which free radical in common?



E.11.2 Explain the role of ammonia in acid deposition

1. Draw the Lewis dot diagram of ammonia.

See #1 above

2. How many charge centers does the central atom of ammonia have?

4

3. Describe the central atom of ammonia in terms of paired electrons and lone pairs of electrons.

The central atom, N, has 4 e- pairs around it - 3 bonding pairs and one lone pair

4. What is the VSEPR shape of the ammonia molecule?

Trigonal pyramidal

5. What are the bond angles of ammonia? Explain your answer.

H-N-H bond angles are approximately 107° which are slightly less than the tetrahedral shape (109.5°), which is typical of 4 charge centres. This is due to the lone pair taking up more space and reducing the bond angles.

6. Is ammonia a Bronsted-Lowry acid or base? Explain your answer.

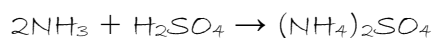
Bronsted-Lowry base as it is able to accept a proton to form the ammonium ion

7. Is ammonia a Lewis acid or base? Explain your answer.

Lewis base as it is able to donate a lone pair of e-

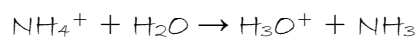
8. Ammonia in the atmosphere neutralises both sulfuric acid and nitric acid forming ammonium salts.

9. Write BOTH equations for the reactions in question 7 above.



10. Ammonium sulfate and ammonium nitrate are acidic salts. Explain why. Write equations to support your answer.

Both salts are made from a strong acid and a weak base. The conjugate acid of the weak base will react with water to produce some hydronium ions in solution, increasing acidity. However, the conjugate base of the strong acids will not react with water and are therefore neutral. So, overall, the salts are weakly acidic.



11. How are these salts taken out of the atmosphere?

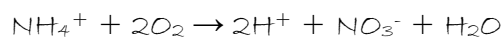
These salts are washed out of the atmosphere by rain as they are soluble in water

12. Which nitrogen molecule is used by plants?



13. How is ammonia converted to the correct type of nitrogen molecule utilized by plants? Write equations to support your answer.

Ammonium ions are converted to nitrates by oxidation (-3 to +5) in a process called nitrification



14. The process by which the ammonium is converted to nitrate is called nitrification

15. What is the catalyst for the above reaction in question 13?

Bacteria catalyse this reaction

16. The process described above in question 13 causes the soil to be acidic or basic? Explain your answer.

Acidic - hydrogen ions are produced

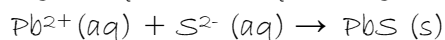
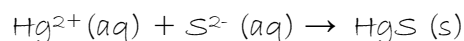
E12 Water and Soil

E.12.1 Solve problems relating to the removal of heavy-metal ions, phosphates and nitrates by chemical precipitation. References: <http://www.usetute.com.au/solrules.html> and <http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch18/ksp.php>

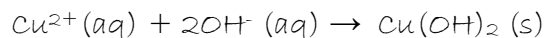
1. Heavy metals such as Hg, Pb, Cd and Zn can be removed by precipitation as a sulfide because many metal sulfides are insoluble in water. Name two substances that contain sulfur that could be added to cause this precipitation

H_2S (hydrogen sulfide gas) Na_2S (sodium sulfide or some other soluble sulfide)

2. Write an ionic equation to represent two of the metals in #1 being removed by precipitation.



3. Heavy metals such as copper, cobalt and iron can be removed by precipitation as a hydroxide. Show how copper is removed in this way.



4. Recall the general mathematical expression for an equilibrium constant, K.

$$K = \frac{[products]}{[reactants]}$$

5. What state of matter is not considered in an equilibrium constant expression?

solids

6. What is the symbol for the solubility product constant?

K_{sp}

7. State the general expression for the solubility product constant for a salt M_mN_n .

$$K_{sp} = [M]^m[N]^n$$

8. Why is water not included in solubility product expressions?

The amount of water is a constant

9. What is the only factor that can affect K_{sp} for a specific salt?

temperature

10. How does K_{sp} relate to whether a precipitate will form or not?

A precipitate will form if the product of the concentration of ions in the mixture, when substituted into the K_{sp} expression exceeds the value of K_{sp}

11. Explain what is meant by the common ion effect.

When there is a precipitate formed, there is some (sometimes only slight) solubility of the ions in solution. For example:



According to Le Chatelier's Principle, the addition of either ion (a common ion) will shift the equilibrium to the left and make the salt less soluble. This is known as the common ion effect.

12. The K_{sp} of $PbCl_2$ is $2.4 \times 10^{-4} \text{ mol}^3 \text{ dm}^{-9}$ at 25°C .

a. Construct a balanced equation for the equilibrium of this salt.



b. Write the solubility product expression.

$$K_{sp} = [Pb^{2+}][Cl^-]^2$$

If,

$$[Pb^{2+}] = x$$

$$[Cl^-] = 2x$$

$$K_{sp} = x(2x)^2$$

c. Calculate the molar solubility of a saturated solution of lead chloride at 25°C .

$$K_{sp} = x(2x)^2 = 4x^3 = 2.4 \times 10^{-4}$$

$$x = 1.8 \times 10^{-6} \text{ mol} \cdot \text{dm}^{-3}$$

d. If the concentration of ions are: $[Pb^{2+}] = 1.0 \times 10^{-2}$ and $[Cl^-] = 2.0 \times 10^{-3}$, predict if there will be a precipitate. Show working.

$$[Pb^{2+}][Cl^-]^2 = [1.0 \times 10^{-2}][2.0 \times 10^{-3}]^2 = 2.0 \times 10^{-8}$$

This is less than K_{sp} , so there is not a precipitate formed

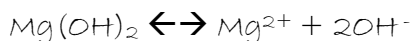
e. What is the minimum amount of Cl^- ions that will produce a precipitate in part (d).

$$K_{sp} = [\text{Pb}^{2+}][\text{Cl}^-]^2 = [1.0 \times 10^{-2}](4x^2) = 2.4 \times 10^{-4}$$

$$[\text{Cl}^-] = 2x = 4.9 \times 10^{-3} \text{ mol.dm}^{-3}$$

13. Water containing $0.010 \text{ mol dm}^{-3}$ magnesium ions precipitates magnesium hydroxide on the addition of sodium hydroxide. Given $K_{sp} = 1.0 \times 10^{-11} \text{ mol}^3 \text{ dm}^{-9}$:

a. Calculate the concentration of Mg^{2+} left in solution when enough NaOH is added to produce a hydroxide concentration of $0.010 \text{ mol dm}^{-3}$.



$$[\text{Mg}^{2+}] = x$$

$$[\text{OH}^-]^2 = 1.0 \times 10^{-4}$$

$$K_{sp} = x(1.0 \times 10^{-4}) = 1.0 \times 10^{-11}$$

$$x = 8.9 \times 10^{-8} \text{ mol.dm}^{-3}$$

b. Calculate the percentage of Mg^{2+} remaining in the solution.

$$\% \text{Mg left} = (8.9 \times 10^{-8} / 0.010) \times 100 = 8.9 \times 10^{-4} \% \text{Mg}$$

14. Determine the order of decreasing molar solubility of the following silver salts. Show working.

Silver salt	K_{sp}
AgCl	$1.0 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$
Ag_2CO_3	$6.3 \times 10^{-12} \text{ mol}^3 \text{ dm}^{-9}$
Ag_3PO_4	$2.0 \times 10^{-21} \text{ mol}^4 \text{ dm}^{-12}$

$$K_{sp} = [\text{Ag}^+][\text{Cl}^-] = x^2 = 1.0 \times 10^{-10} \quad x = 1.0 \times 10^{-5} \text{ mol.dm}^{-3}$$

$$K_{sp} = [\text{Ag}^+]^2[\text{CO}_3^{2-}] = 4x^3 = 6.3 \times 10^{-12} \quad x = 1.2 \times 10^{-4} \text{ mol.dm}^{-3}$$

$$K_{sp} = [\text{Ag}^+]^3[\text{PO}_4^{3-}] = 27x^4 = 2.0 \times 10^{-21} \quad x = 2.9 \times 10^{-6} \text{ mol.dm}^{-3}$$

Therefore, decreasing solubility: $\text{Ag}_2\text{CO}_3 > \text{AgCl} > \text{Ag}_3\text{PO}_4$

15. Work through the examples and problems in Derry, pp 312-313.

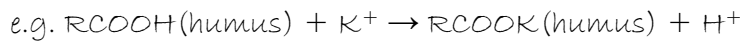
E.12.2 State what is meant by the term cation-exchange capacity (CEC) and outline its importance.

1. Define cation-exchange capacity.

CEC is the extent to which the negative ions on clay or humus in soil can exchange nutrient cations with the roots of plants. It is measured by the number of moles of singly charged positive ions that are able to be held in 1kg of soil.

2. What is humus?

Humus is a rich, organic substance formed from the decay of plant matter, left over after the decomposition by bacteria in the soil. It contains humic acids, which are weak carboxylic acids that partially dissociate to negative carboxyl anions. These anions are able to bind to positively charged nutrients.



3. Which cations are important plant nutrients?

K^+ Ca^{2+} Mg^{2+} are most important cations

There are also micronutrients (trace elements) that are also important in small quantities including: $\text{Fe}^{2+/3+}$, Cu^{2+} , Zn^{2+}

4. What does CEC indicate?

CEC indicates soil fertility – the larger the CEC, the more cations the soil can absorb, which can be made available for plants.

5. CEC values depend on what two factors?

- Amount of clay
- Amount of organic material (humus)

6. What is the advantage of having organic matter in the soil?

It has a high CEC content as opposed to sandy soils which do not hold cations. This means they are easily washed away.

7. Using a dictionary, define the word adsorb. (Not absorb, adsorb)

To accumulate gases, liquids or solids on the surface of a liquid or solid (source: the freedictionary.com)

8. Explain in detail how adsorption of cations occurs in soil organic matter and in clay.

Humus and clay contain negative charges on their surfaces. This leads to electrical attraction of the positively charged cation nutrients in the soil.

Clays are made of silicates. The silicon atoms have an oxidation of +4. These are often replaced by Al^{3+} ions in the soil (oxidation of +3). This leaves the clay with an overall negative charge that can attract nutrient cations.

Humus has a large surface area and contains many negatively charged sites due to the partial dissociation of the carboxylic acid groups on its surface. Again, this can attract nutrient cations.

9. How does humus increase CEC?

By adsorbing the nutrient cations on its surface, making them available for plants

E.12.3 Discuss the effects of soil pH on cation-exchange capacity AND availability of nutrients. Reference: Green and Damji, 3rd ed.

1. What key roles does water play in soil?

- Many cations such as Na^+ and K^+ are soluble in water
- Other compounds such as ZnS and Al_2O_3 are insoluble in water, but react with H^+ and OH^- ions that are soluble in water

2. Why is natural rain water slightly acidic? Write equations to support your answer.

Rain water is acidic due to the reaction of water vapour with carbon dioxide in the atmosphere



3. What is the pH of natural rain water?

5.6

4. What affect does acidic soil have on metal ions?

Metals have greater solubility

5. Write the chemical formula for zinc (II) sulfide.

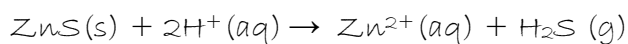
ZnS

6. State the solubility rule that indicates whether or not zinc sulfide is soluble in water.

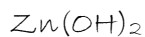
All sulfides except those in Groups I, II and NH_4^+ are insoluble. Therefore, insoluble

7. How does zinc sulfide behave differently in a slightly acidic solution than water? Write equations to support your answer.

Greater solubility as it reacts with acid to form hydrogen sulfide gas



8. Write the chemical formula for zinc (II) hydroxide.

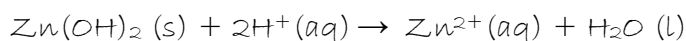


9. State the solubility rule that indicates whether or not zinc hydroxide is soluble in water.

All hydroxides except those of the alkali metals are insoluble. Therefore, insoluble

10. How does zinc hydroxide behave differently in a slightly acidic solution than water? Write equations to support your answer.

Again, more soluble



11. Alumina is a common name for the compound aluminum oxide. Write the chemical formula for aluminum oxide.

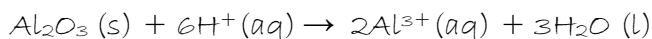


12. State the solubility rule indicating whether or not aluminum oxide is soluble in water.

All oxides except alkali metals are insoluble. Therefore, insoluble

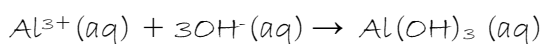
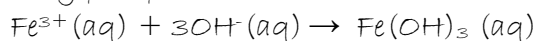
13. How does aluminum oxide behave differently in a slightly acidic solution than water? Write equations to support your answer.

More soluble



14. What happens to aluminum and iron ions in basic conditions? Write equations to support your answer.

They precipitate out:



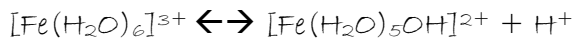
15. Define 'high charge density' as it relates to hydrated ions.

Hydrated ions such as $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ and $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ have a high charge to size ratio.

A high charge to size ratio is known as a high charge density

16. What do high charge density ions produce AND why? Write equations to support your answer.

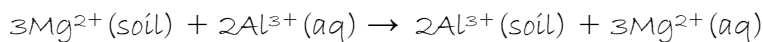
H^+ ions



17. Name 2 ions that are toxic to plants AND explain how they can replace ions that are nutrients. Write equations to support your answer.

Al and Mn

Due to the high charge density of Al^{3+} it is able to replace important plant nutrients such as Ca^{2+} and Mg^{2+} on the surface of clay and humic soils.



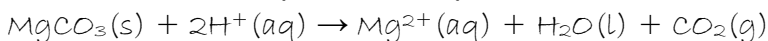
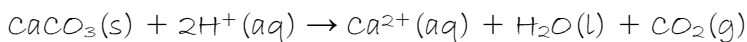
18. Define ligand.

A molecule or ion that is able to form an attachment to a central metal ion as a coordinate bond. Ligands have a spare pair of electrons to donate

19. Define chelating effect.

When a ligand forms attachments to the central atom in more than one location

20. Write equations demonstrating how calcium ions and magnesium ions are lost to water drainage while in acidic soil.



These ions can then be washed away by water drainage

21. How can the ions in question 20 be replenished?

Calcium carbonate and magnesium carbonate can be added to the acidic soil

22. Acidic soil below pH 5.5 affects microbes' ability to fix N_2 to NH_4^+ . Why is nitrogen fixing important to plants?

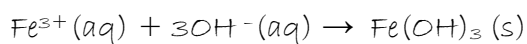
Nitrogen must be in the correct form to be absorbed by plants. They cannot use gaseous nitrogen and most often use ammonium or nitrates.

23. How can soil pH be altered to pH 6?

With the addition of lime (CaO)

24. What happens if soil pH increases too much? Write equations to support your answer.

Ions such as Fe^{3+} and others will precipitate out and not be available for plants



25. Is phosphoric acid a weak or strong acid?

Weak acid

26. Phosphoric acid is triprotic. Define triprotic?

A triprotic acid is one with 3 donatable hydrogen atoms

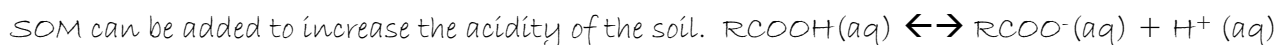
27. In order for plants to obtain phosphorous, soil must be between pH 6 and 7.5. Explain what happens to phosphorous when the pH is too acidic AND too basic.

Too acidic: insoluble Fe and Al phosphates form, reducing the amount of phosphorus to plants

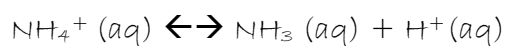
Too basic: insoluble Ca and Mg phosphates precipitate

28. Micro-nutrients are available in acidic soil. Explain what happens if the soil becomes too basic mentioning how to rectify the basic soil. Write equations to support your answer.

Fe, Mn and Zn ions will form insoluble hydroxides as the pH reaches 7 or above.



Also, ammonium sulfate can be added as it is weakly acidic due to the weak base it is made from



29. CEC depends on soil pH. How does SOM act as a buffer? Write equations to support your answer. (To answer this question you may want to briefly read about Le Chatelier's principle)



As seen in the equation above, this is a weak acid and its conjugate base, which makes an effective buffer system.

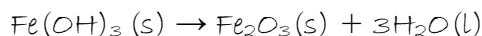
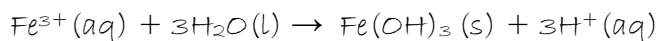
As acid is added, it reacts with the carboxyl ion to form a weak acid (shifts left). This means less anion sites available for binding to nutrient cations.

As base is added, H^+ ions are reduced, shifting the equilibrium right, producing more cations that can bind to nutrients in the soil.

E.12.4 Describe the chemical functions of soil organic matter (SOM). Reference: Green and Damji, 3rd ed.

1. One of the chemical functions of SOM is to increase the CEC of the soil. Briefly explain how this happens. Write equations to support your answer.

SOM contains negative charges due to substances such as carboxyl ions which are able to bind to positive nutrients. If these ions are not able to bind to SOM, they may be washed away or precipitate out as insoluble oxides and hydroxides.



2. Another of the chemical functions of SOM is to enhance the ability of soil to buffer changes in pH. Briefly explain how this happens. Write equations to support your answer.



Acid added: shifts left using up some of the added acid

Base added: shifts right, OH reacting with the acid present

These minimize the changes to pH in the system

3. Another of the chemical functions of SOM is to bind to organic and inorganic compounds in soil. Briefly explain how this happens. Write equations to support your answer.

SOM binds to organic and inorganic compounds to make them available for plants. For example, phosphorous in the form of PO_4^{3-} (phosphate ions) and H_2PO_4^- (orthophosphates) comes from organic (an ester of phosphoric acid) and inorganic (phosphoric acid salts) sources. Phosphates are important for the development of plant roots, allows flowering and prevents the yellowing of leaves. SOM binds to phosphates to make them available to plants. (equations not necessary)

4. Another of the chemical functions of SOM is to reduce negative environmental effects of pesticides, heavy metals and other pollutants by binding contaminants. Briefly explain how this happens. Write equations to support your answer.

SOM is able to chelate toxic substances such as pesticides and toxic heavy metals. Pesticides can then be broken down by soil microbes. This reduces the amount of toxic substances available to plants and also reduces the amounts that end up in the water supply. (equations not necessary)

5. The last example of the chemical functions of SOM is it forms stable complexes with cations. Briefly explain how this happens. Write equations to support your answer.

SOM forms stable complexes with cations that may otherwise precipitate out. Previous examples were given for iron and aluminium.

Answer the questions in chapter 5 in Derry, et.al. *Chemistry Options: SL and HL*