Experiment 12

Chemistry of Soil

The Task

The goal of this experiment is to determine which salts could be added to soil to increase or decrease its pH.

Skills

At the end of the laboratory you should be able to:

- use universal indicator to determine soil pH,
- work cleanly, avoiding contamination of one chemical with another,
- write a balance equation for an acid-base reaction.

Other Outcomes

- You will understand the concept of pH and how metal salts can affect its value.
- You will appreciate how a buffer maintains a constant pH.

The Assessment

You will be assessed on your ability to write equations properly. Equations should be properly balanced and the states of all species indicated correctly. Make sure that you use the correct symbols for atoms, that you indicate the charges on all ions correctly, and that you omit all spectator ions.

Introduction

If you are a gardener you may know that hydrangeas generally flower blue in Sydney, whereas in Adelaide the flowers are almost always pink. What is the reason for this? The answer is soil pH. In the Sydney region the soil is relatively acidic, whereas on the Adelaide plains the soil is more basic (or alkaline). pH is defined as the negative logarithm to the base 10 of the H^+ concentration:

$$pH = -\log_{10}[H^+]$$

Soil pH doesn't just determine the colour of hydrangeas. All plants have particular pH range preferences. Here are a few examples:

pH 4.5 – 5.0	azalea, heather, blueberry
pH 5.0 – 5.5	camellia, potato, rhododendron
pH 5.5 – 6.0	daffodil, carrot, petunia
pH 6.0 – 6.5	gladiolus, cabbage, snapdragon
pH 6.5 – 7.0	carnation, onion, dahlia
pH 7.1 – 8.0	lilac, cactus

The reason for these preferences is that the soil pH determines the chemical form of nutrients present in the soil, which determines their bioavailability, *i.e.* the degree to which they can be taken up by the plant. All plants have evolved so that they can thrive under the soil pH conditions prevalent in their original natural environment. Therefore, if you wish to grow a plant, whose preferred pH range is different from that of your garden, you will need to adjust the soil pH of your garden bed. In this experiment you will learn what controls the pH of soil, how one can measure it and how the pH can be adjusted.

Safety

Chemical Hazard Identification

zinc sulfate – moderate toxicity, irritant. Avoid eye or skin contact and inhalation.

magnesium nitrate – oxidising agent, moderate toxicity, moderate irritant. Avoid inhalation, contact with eyes, skin or combustible materials.

sodium nitrate – oxidising agent, moderate toxicity - irritant. Avoid inhalation, contact with eyes, skin or combustible materials.

sodium acetate – low toxicity low irritant.

sodium phosphate – low toxicity - irritant - slightly corrosive. Avoid eye or skin contact and inhalation.

aluminium nitrate – oxidising agent, moderate toxicity, moderate irritant. Avoid inhalation, contact with eyes, skin or combustible materials.

ammonium sulfate – low to moderate toxicity, low to moderate irritant. Avoid eye or skin contact and inhalation.

sodium hydrogencarbonate – low toxicity – low irritant.

calcium carbonate – low toxicity – irritant.

ammonium iron(III) sulfate – low toxicity, irritant. Avoid eye or skin contact and inhalation.

ammonium iron(II) sulfate – low toxicity, irritant. Avoid eye or skin contact and inhalation.

barium sulfate – low toxicity - low irritant.

universal indicator – low toxicity irritant. Avoid eye or skin contact.

1 M hydrochloric acid – hazardous, causes burns; irritating to respiratory system.

0.1 M hydrochloric acid – non-hazardous. Avoid eye or skin contact or inhalation.

10 M HCl - corrosive, irritant. Avoid eye or skin contact and inhalation.

0.1 M sodium hydroxide – slightly corrosive – irritant. Avoid eye and skin contact.

sodium hydrogenphosphate – low toxicity - low irritant.

sodium dihydrogenphosphate – low toxicity - low irritant.

Risk Assessment and Control

Low risk

Avoid contact with chemicals and solutions.

Waste Disposal

All of the solutions used today can be washed down the sink with water. Soil samples to be placed in containers provided.

Experimental

This experiment is to be carried out in pairs.

If practical, you should bring a soil sample from home to analyse.

Part A pH of salt solutions

In this part of the experiment you will determine what effect a range of different salts have on the pH of water.

The slightest amount of cross contamination will cause spurious results. Make sure you wash and dry your spatula before you take each sample. Equally important is to make sure you replace the lid of the container after you have taken each salt.

(A1) In a clean 250mL beaker collect 150 mL of freshly boiled deionised water to which universal indicator has already been added. Take 10 mL in a test-tube as a reference solution. To separate tubes containing 10 mL of the water add 0.1 g (you don't need to weigh it; see the front of the lab for roughly how much 0.1 g is) of each of the following salts.

$NaNO_3$, $(NH_4)_2SO_4$, $ZnSO_4{\cdot}7H_2O$, $Mg(NO_3)_2{\cdot}6H_2O$, $NaCH_3CO_2{\cdot}3H_2O$, $Na_3PO_4{\cdot}12H_2O$, $Al(NO_3)_3{\cdot}9H_2O$, $NaHCO_3$, Na_2CO_3, $CaCO_3$, $NH_4Fe(SO_4)_2{\cdot}12H_2O$, $(NH_4)_2Fe(SO_4)_2{\cdot}6H_2O$*

*Add a small amount of iron filings to this solution to reduce any Fe^{3+} ions that may be present to Fe^{2+} ions. Stir well and then leave to stand for a few minutes before observing the indicator colour.

(A2) Construct a table in your logbook with the following heading: "Salt", pH and "Constituent ions", Change due to". In your table list each salt, the ions it's composed of and the pH of its solution based on the colour of the universal indicator.

For your logbook:

Based on your observations of whether the salt caused an increase in acidity (decrease in pH) or an increase in alkalinity (increase in pH), write down equations to explain the pH changes. If there was no change, explain why that was the case. Hint: Strong acids such as HCl, H_2SO_4 and HNO_3 and strong bases such as NaOH dissociate strongly and won't reform in aqueous solution. Weak acids such as H_2CO_3 and H_3PO_4 can reform in solution via the transfer of an H^+ ion from H_2O. Weak bases such as NH_3 can reform in solution via the transfer of an H^+ ion to H_2O.

Part B Buffer solutions

In this part of the experiment you will determine the effect of adding strong acid (HCl) or strong base (NaOH) to a solution containing a mixture of sodium dihydrogenphosphate (NaH_2PO_4) and sodium hydrogenphosphate (Na_2HPO_4). $H_2PO_4^-$ and HPO_4^{2-} are both examples of ions which could be present in soil.

(B1) Take 60 mL of the $H_2PO_4^-/HPO_4^{2-}$ pH 7.0 buffer solution in a 100 mL beaker and set up 5 test-tubes each containing 10 mL of buffer. Add universal indicator (4 drops) to each tube and mix the contents thoroughly.

(B2) To each test tube, add 2 drops of each of the following, mix thoroughly and record the final colour of solution and the corresponding pH in a table in your logbook.

nothing (reference tube), 0.1 M HCl, 0.1 M NaOH, 1 M HCl, 10 M HCl

(B3) Set up 3 test-tubes, each containing 10 mL of the freshly boiled deionised water containing universal indicator.

(B4) To separate tubes, add 2 drops of each of the following, mix thoroughly and record the final colour of solution and the corresponding pH in a table in your logbook.

nothing (reference tube), 0.1 M HCl, 0.1 M NaOH

For your logbook:

Which solution was best able to withstand changes in pH after adding acid or base, the NaH_2PO_4/Na_2HPO_4 solution or the water?

Write equations to explain your observations.

A NaH_2PO_4/Na_2HPO_4 solution is an example of what is called a “buffer”. Can you explain why this term is used?

Part C Measuring the pH of soil

In this part of the experiment you get to measure the pH of a real soil sample.

(C1) Place a spatulaful of soil on a white tile.

(C2) Add indicator until the sample can be stirred into a thick paste.

(C3) Sprinkle barium sulfate powder over the paste.

(C4) Wait for approximately one minute and then **record the pH value of the soil in your logbook**. Use the colour chart provided with the kit to estimate the pH.

(C5) Disperse a sample of the soil in a small amount of the freshly boiled deionised water containing the universal indicator in a large test tube. Add 5 drops of 1 M HCl and watch very carefully for any reaction. Record your observations in your logbook.

For your logbook:

Based on the pH you measured, what plants do you think might grow well in that soil (see the Introduction)?

Group Discussion

If you wished to increase the pH of soil, *i.e.* make it more basic (alkaline), which salt would you add to the soil?

If you wished to decrease the pH of soil, *i.e.* make it more acidic, which salt would you add to the soil?

If the pH of the soil is above 7.5 it is almost impossible to make it more acidic. Can you explain this?

Compare the results from step (C5) for the different types of soils. Why do some soils react and others don't? What is happening?