Chemistry in geology

Education in Chemistry
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The chemistry you learn is key in helping geologists identify the origin, age and composition of rocks

Geologists use the radioactive decay of isotopes to work out the age of rocks. Mass spectrometry can be used to identify isotopes of elements.

Isotopes

1. In terms of fundamental particles, state the similarities and difference between different isotopes of an element.

2. Explain why isotopes of an element have the same chemical properties.

3. Give the meaning of the term 'relative atomic mass'.

4. Explain why the relative atomic mass of a sample of chromium found on an asteroid might be different to the relative atomic mass of chromium on the periodic table.

5. Explain whether or not you would expect the chemical reactions of the chromium found on an asteroid to be different to the reactions of a sample of chromium mined from the Earth.

Mass spectrometer – time of flight

1. A time of flight (TOF) mass spectrometer can be used to determine the relative atomic mass of an element. Explain why it is necessary to ionise atoms of the element when measuring their mass in a TOF mass spectrometer.

2. Describe how an atom is ionised in the TOF mass spectrometer by electron impact. Write an equation with state symbols, to represent this ionisation for a Cr atom.

3. How does a TOF mass spectrometer accelerate the ion formed by electron impact?

4. Why does a TOF mass spectrometer need to be kept under a vacuum?

5. Explain how a TOF mass spectrometer will separate the different ions passing through it in the drift zone.

6. $^{55}Fe^{+}$ and $^{57}Fe^{+}$ ions are passing through a time of flight spectrometer. Explain which will pass through first.

7. Two measurements for each isotope are recorded on the mass spectrum. State the two measurements that are recorded for each isotope.

8. The table below gives the percentage abundance of each isotope in the mass spectrum of a sample of titanium.

m/z	46	47	48	49	50
% abundance	8.02	7.31	73.81	5.54	5.32

Use the above data to calculate the value of the relative atomic mass of titanium in this sample. Give your answer to one decimal place.

Dating rocks

An isotope of potassium ^{40}K is often found in rocks. It can change to ^{40}Ar through radioactive decay.

The half-life for the decay of ^{40}K is 1.26×10^9 years.

1. Compare the number of protons and neutrons in ^{40}K and ^{40}Ar and suggest what happened during the decay.
2. Explain how measuring the amount of ^{40}Ar in a rock can help find the rocks age.
3. Suggest why it is difficult to age a sedimentary rock from the measuring the decay of isotopes.

Potassium–argon dating

Potassium–argon dating is used to date some rocks based on the radioactive decay of an isotope of potassium (^{40}K) into argon (^{40}Ar). As a noble gas, argon does not bind with other atoms in the rock's crystal lattice structure and instead remains trapped within the spaces. However, it is able to escape molten rock when the crystals melt, then starts to accumulate when the rock recrystallises. The method can therefore tell researchers how long it has been since a rock sample has solidified. Mass spectrometry can detect the amount of argon gas released from a sample. Potassium–argon dating was used by the Mars Curiosity rover to date a rock sample on the red planet back in 2013.

Chemistry in geology – answers

Isotopes

1. Different number of neutrons.
   Same number of protons and electrons.

2. Same electronic configuration or same number of electrons in the outer shell.

3. Relative atomic mass is the weighted mean mass of one atom compared to one twelfth of the mass of one atom of carbon-12.

4. Different abundances of the different isotopes of the element.

5. Should be the same because the element has the same electronic configuration.

Mass spectrometer – time of flight

1. Ions will interact with and be accelerated by an electric field.
   Only ions will create a current when hitting the detector.

2. A vaporised sample is injected at low pressure.
   An electron gun fires high energy electrons at the sample this knocks out an outer electron forming positive ions.
   $Cr (g) \rightarrow Cr^{+} (g) + e^{-}$

3. Positive ions are accelerated by an electric field to a constant kinetic energy.

4. It needs to be under a vacuum otherwise air particles would ionise and register on the detector.

5. The positive ions with smaller m/z values will have the same kinetic energy as those with larger m/z and will move faster.
   Therefore, ions with smaller m/z will arrive at the detector first.

6. Positive ions are accelerated by an electric field to a constant kinetic energy.
   The positive ions with m/z of 55 have the same kinetic energy as those with m/z of 57 and move faster.
   Therefore, ions with m/z of 55 arrive at the detector first.

7. mass/charge
   abundance

8. 47.9

Dating rocks

1. ^{40}K has 19 protons and 21 neutrons.
   ^{40}Ar has 18 protons and 22 neutrons.
   One proton has turned into a neutron.

2. The argon produced is trapped in the rock.
   The ratio of ^{40}K to ^{40}Ar will change over time.
   The ratio of ^{40}K to ^{40}Ar in the rock can be used to date the rock.

3. Sedimentary rocks are made from fragments of older rocks.
   If there is a mixture of different rocks then each component will have its own age.
   It is difficult to know when the fragments came together to make the sedimentary rocks.