Why do mushrooms eat rocks?

Key Stage 4 Programme

Pupil Name

Handbook Designed by Dr. R. Thorley

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
6 (Feedback)			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on 19 July	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

The Brilliant Club KS4 Programme – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at AS-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

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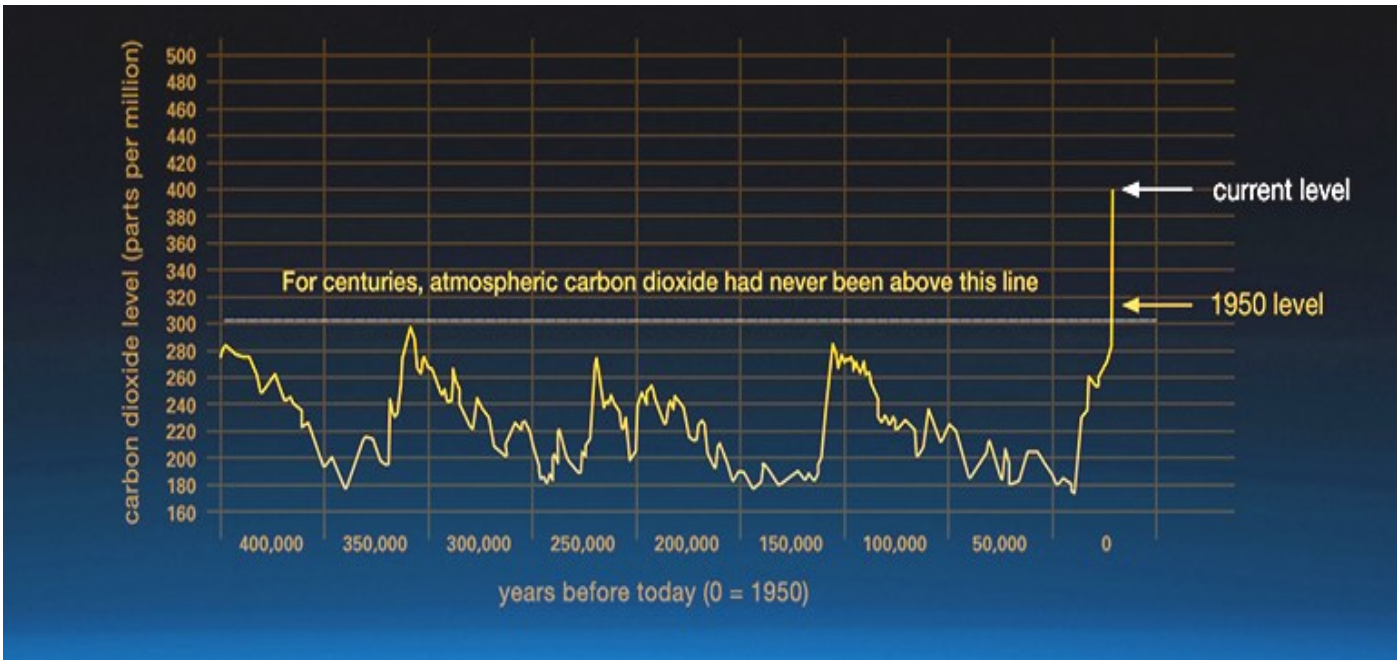
Course Rationale

By investigating current climate change research, this course aims to provide thorough preparation for studying science at A-Level or university through honing skills in data handling and interpretation. This course introduces interdisciplinary research, combining elements of chemistry, physics, biology and geology to go beyond conventional classroom science. The ability to combine ideas and skills from different disciplines , and support with personal statement writing, will give students a head-start for pursuing scientific careers.

Throughout history, Earth's climate has changed, cycling through warm periods and cooler periods. Global temperature is regulated by greenhouse gases, the main one of these is carbon dioxide (CO_2). However, over the last 200 years, human activities including industry, driving cars and deforestation have caused global warming by releasing greenhouse gases into the atmosphere far faster than naturally. In 2016, atmospheric CO_2 broke the record for the highest concentration in the last 10-20 million years! Global warming is creating many problems, melting ice caps and glaciers, damaging crops, endangering species, and threatening peoples' lives and homes in coastal communities.

To reduce climate change, we must reduce the amount of CO_2 in the atmosphere. In this course, we will look into current interdisciplinary research on rock weathering, one of the main ways in which CO_2 is removed from the atmosphere. Some of the chemical reactions that make rocks break down, or weather, use up CO_2, taking it out of the atmosphere. This process is called carbon sequestration. How does the biological activity of forests increase rock weathering in soils, and what affect does this have on climate change?



Mark Scheme Table

	Skills	1st (70-100)	2:1 (60-69)	2:2 (50-59)
Subject knowledge	Knowledge and Understanding	• All content included is relevant to the general topic and to the specific question/title • Good understanding of all the relevant topics. • Scientific terms are defined and used accurately throughout • Clear justification on how the content included is related to the specific issues that are the focus of the assignment	• Most of the content included is relevant to the general topic and to the specific question/title • Good understanding of most the relevant topics • Scientific terms are used accurately but not always clearly defined. • Adequate justification on how the content included is related to the specific issues that are the focus of the assignment	• Some of the content included is relevant to the general topic and to the specific question/title • Good understanding on some of the relevant topics but occasional confusion on others. • Scientific terms are used mostly accurately with occasional confusion and often not defined. • Some justification on how the content included is related to the specific issues that are the focus of the assignment
Critical Thinking	Research and Evidence	• Inclusion of rich sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas • Use evidence/ calculations to support claims/ assertions/ideas, consistently clearly and convincingly • Evidence of further reading beyond materials provided which were used in an appropriate context • Data is effectively analysed and appropriate assumptions/ conclusions are reached	• Inclusion of adequate sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas • Use evidence/calculations to support claims/assertions/ ideas, mostly clearly and convincingly • Evidence of further reading beyond materials provided • Data is analysed and the assumptions/conclusions that are reached are mostly appropriate	• Inclusion of some sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas • Use evidence/ calculations to support claims/ assertions/ideas, at times clearly and convincingly • Limited evidence of further reading beyond materials provided • There is an attempt to analyse data is and draw assumptions/ conclusions

Critical Thinking	Developing an Argument	• A point of view or position in relation to the title or question is consistently clear • Argument/proof exceptionally well-developed and well-justified • A position is clearly established in relation to the question, and is developed effectively and consistently throughout the essay • Makes links effectively between subjects that have not previously been associated • Uses concepts from the tutorials in an unfamiliar context, and does so accurately and confidently. • Content is analysed effectively to support the argument	• A point of view or position in relation to the title or question is adequately clear • Argument/proof clear and well-developed and position justified • A position is established in relation to the question, and is well-developed in most of the essay • Some evidence of linking subjects that have not previously been associated • Use some concepts from the tutorials in an unfamiliar context, but not always accurate • Analysis of content to support the argument	• A point of view or position in relation to the title or question is somewhat clear • Argument/proof clear but not well-developed • A position is established in relation to the question, and is well-developed in parts of the essay • Limited evidence of linking subjects that have not previously been associated • Limited use of concepts from the tutorials in other contexts • Some analysis of content to support the argument
	Critical Evaluation	• Moved beyond description to an assessment of the value or significance of what is described • Evaluative points are consistently explicit/ systematic/ reasoned/justified • Effective critiques on the reliability of sources provided	• Mostly description but some assessment of the value or significance of what is described • Evaluative points are mostly explicit/ systematic/ reasoned/justified • Some evidence of critiques on the reliability of sources provided	• Only description with minimal assessment of the value or significance of what is described • Evaluative points are at times explicit/ systematic/ reasoned/justified • Limited evidence of critiques on the reliability of sources provided

Written Communication	Structure and Presentation	• Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment • The introduction clearly outlines how the essay/report will deal with the issues • The conclusion summarises all the main points clearly and concisely • All calculations, formulas and methods are clearly structured, clear to follow and correct • Tables and graphs are effectively constructed including appropriate headings, units and scales. • All sources are referenced correctly in an agreed format	• Ideas are presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment • The introduction adequately describes how the essay/report will deal with the issues • The conclusion summarises most of the main points clearly • Calculations, formulas and methods are mostly structured, clear to follow and correct • Most tables and graphs are well constructed • Most sources are referenced correctly in an agreed format	• Ideas are presented in paragraphs and arranged in a structure • The introduction mentions how the essay/report will deal with the issues • The conclusion summarises some of the main points clearly • Calculations, formulas and methods are not always structured, clear to follow and correct. • Some tables and graphs are well constructed but contains some errors • Some sources are referenced correctly in the agreed format with occasional errors
	Language and Style	• No spelling, grammar or punctuation errors • Units and significant figures are presented accurately throughout • Writing style consistently clear, appropriate for scientific documents and easy to follow • Accurate and consistent use of technical language and vocabulary	• Minimal spelling, grammar or punctuation errors • Units and significant figures are presented accurately throughout • Writing style mostly clear, appropriate for scientific documents and easy to follow • Some attempts of using technical language and vocab alary, but not always accurate	• Some spelling, grammar or punctuation errors • Units and significant figures are presented accurately throughout with occasional errors • Writing style moderately clear, appropriate for scientific documents and easy to follow • Use of simple language and vocabulary effectively but struggles to use technical language

Glossary of Keywords

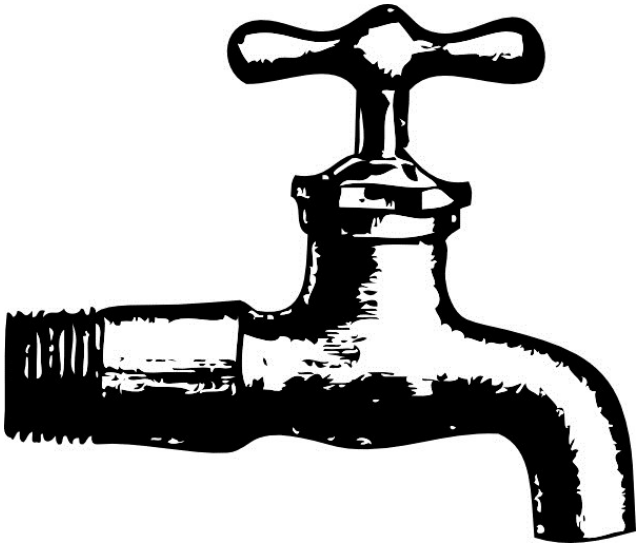
Word	Definition
Anthropogenic	Related to human activity
Carbon dioxide (CO2)	The most common greenhouse gas
Carbon offsetting	The counteracting of carbon dioxide emissions with an equivalent reduction of carbon dioxide in the atmosphere.
Carbonate rock	Rocks in which the main minerals contain carbon
CO2 Sequestration	The process of trapping CO2 from the atmosphere
Deforestation	The process of removing forests to convert an area to farmland or another purpose
Granite	A type of silicate rock
Interdisciplinary	Work which requires knowledge or skills from more than one discipline. Eg. Biology, chemistry, physics amd geology.
Mycorrhizal fungi	Fungi found in soil that form a symbiotic association with plant roots
Photosynthesis	The process by which plants use energy from sunlight to convert carbon dioxide and water into carbohydrates
RCP scenarios	Representative Concentration Pathways (RCP) are a aet of scenarios agreed on by scientists and policymakers that describe different options for CO2 emissions over the next century (2000-2100)
Silicate rock	Rocks in which the main minerals contain silicon
Spectroscopy	The study of how electromagnetic radiation (or light) interacts with matter
Weathering	The process by which rocks break down physically or chemically in-situ
Wollastonite	A common silicate mineral

Tutorial 1 – The Carbon Cycle: Sources and Sinks

What is the Purpose of Tutorial 1?

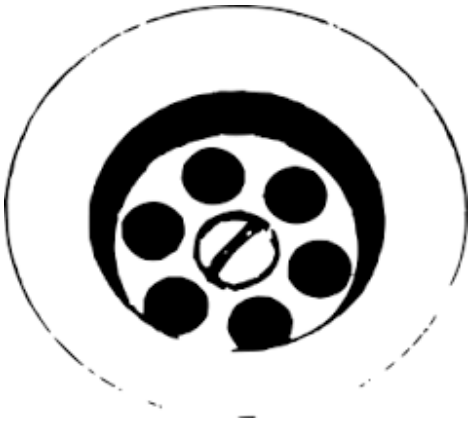
- To be able to give examples of the main anthropogenic sources of CO_2
- To understand how the imbalance between CO_2 sources and sinks leads to climate change
- To identify differences between short and long-term trends, and to understand how RCP scenarios are used to predict future climate change.

Activity 1: Identify some CO2 sources and sinks and place them on the diagram below



Carbon Sources and Sinks

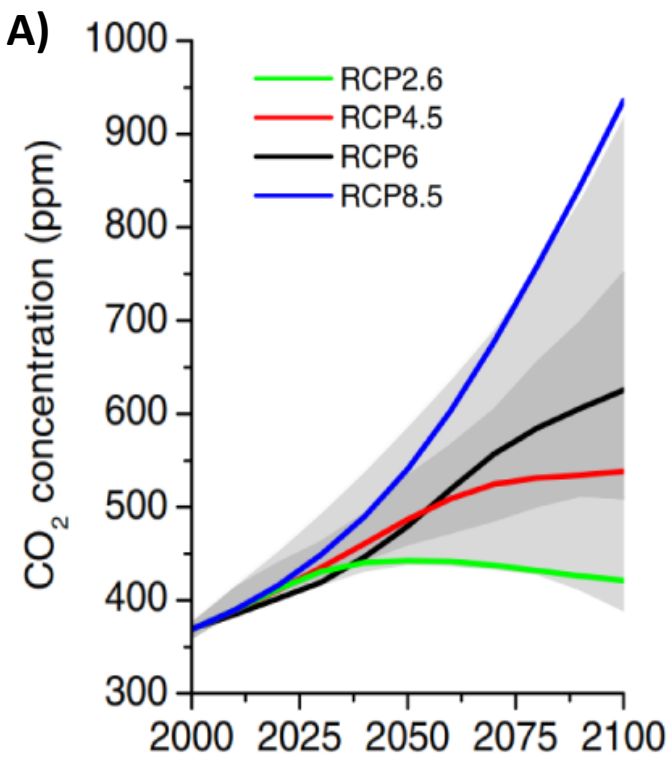
A carbon source is any process or activity that releases carbon into the atmosphere. Both natural processes and people's activities can be carbon sources.
A carbon sink takes up or stores carbon on the Earth.



Representative Concentration Pathways (RCP):

RCPs are scenarios that describe different options for CO_2 emissions over the next century (2000-2100). These scenarios take into account the whole range of climate policies that different countries might choose. Agreeing on a limited number of scenarios helps scientists when they create computer models of future climate change, because they can be sure that they are comparing apples with apples when communicating their results.

Activity 2: The two graphs below are from a scientific journal.
A) This shows the 4 RCP scenarios for atmospheric CO_2 concentration from 2000-2100
B) This shows the predicted global temperature change for 2 of these RCPs



What does ppm stand for?

.....

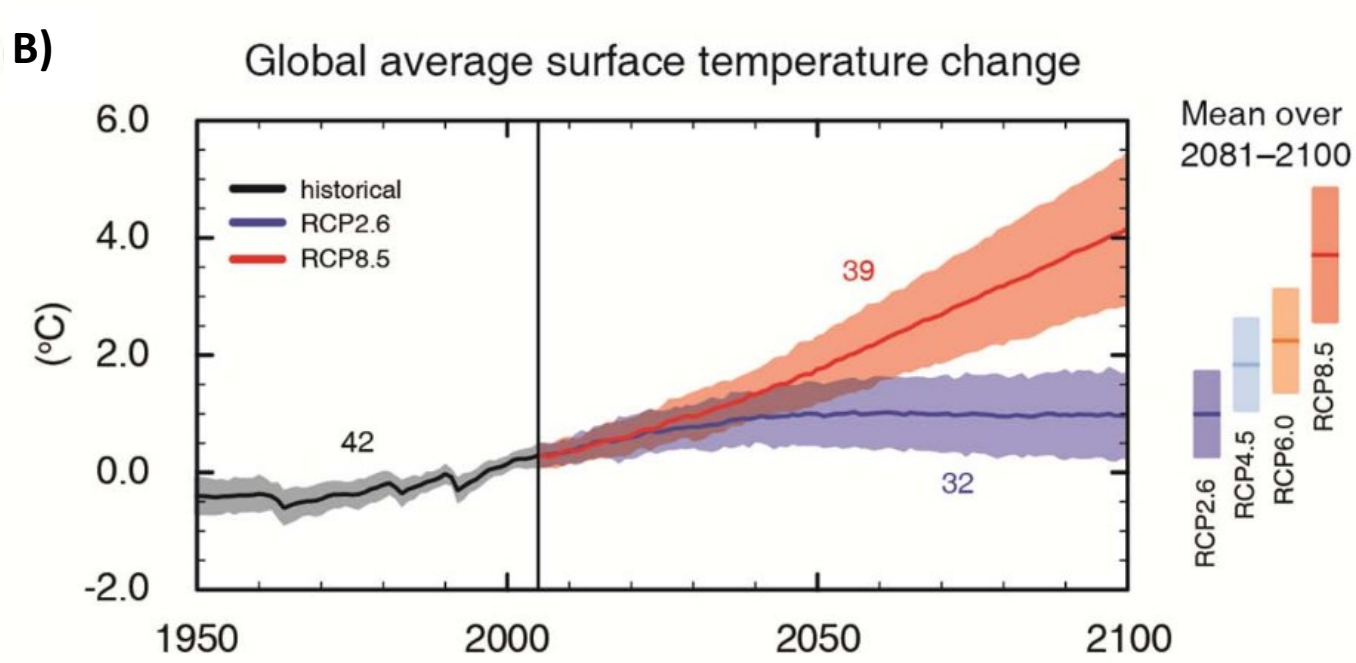
What is 1ppm as a %?

1ppm = ...%

Which RCP has the most CO_2 produced? .....

Which RCP has the least CO_2 produced? .....

RCP 8.5 is known as the **"business as usual"** scenario. This assumes that across the globe, we continue to produce as much CO_2 as we do at the moment. People make no extra effort to reduce emissions or take any CO_2 out of the atmosphere.



Carbon dioxide accumulates in the atmosphere and stays there for decades.
Even if emissions start reducing in 2020, the concentration continues increasing for decades after this.

If we continue 'business as usual', what temperature change will we be likely to see:

by 2050 .....

By 2100 .....

Global CO_2 – and Hawaii!

The longest running dataset for atmospheric CO_2 concentration has been recorded at Mauna Loa volcano in Hawaii. This data is used by scientists around the world, and is the most important set of data for understanding short and long-term changes in atmospheric CO_2.

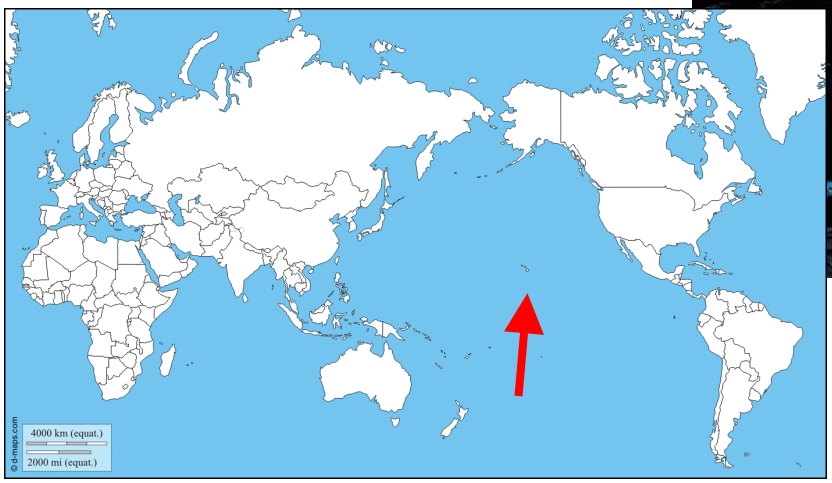
Why are measurements taken in Hawaii?

.....

.....

.....

.....



Carbon through the seasons

The table below contains some of the original atmospheric CO_2 concentration data, recorded at Mauna Loa volcano in Hawaii. Choose one year and use the graph paper on the next page to plot a graph of monthly changes in CO_2 changes over a one–year period. Remember to give your graph an appropriate title (what data are you using, what are you trying to show), and to label your x and y axes.

Mauna Loa CO_2 Monthly Average Concentrations, 2000 to 2011 (ppm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	369.25	369.50	370.56	371.82	371.51	371.71	369.85	368.20	366.91	366.99	368.33	369.67
2001	370.52	371.49	372.53	373.37	373.82	373.18	371.57	369.63	368.16	368.42	369.69	371.18
2002	372.45	373.14	373.93	375.00	375.65	375.50	374.00	371.83	370.66	370.51	372.20	373.71
2003	374.87	375.62	376.48	377.74	378.50	378.18	376.72	374.31	373.20	373.10	374.64	375.93
2004	377.00	377.87	378.73	380.41	380.63	379.56	377.61	376.15	374.11	374.44	375.93	377.45
2005	378.47	379.76	381.14	382.20	382.47	382.20	380.78	378.73	376.66	376.98	378.29	379.92
2006	381.35	382.16	382.66	384.73	384.98	384.09	382.38	380.45	378.92	379.16	380.18	381.79
2007	382.93	383.81	384.56	386.40	386.58	386.05	384.49	382.00	380.90	381.14	382.42	383.89
2008	385.44	385.73	385.97	387.16	388.50	387.88	386.42	384.15	383.09	382.99	384.13	385.56
2009	386.93	387.42	388.77	389.46	390.19	389.44	387.91	385.92	384.79	384.39	386.00	387.27
2010	388.45	389.82	391.08	392.46	392.95	392.03	390.13	388.15	386.80	387.18	388.59	389.68
2011	391.19	391.76	392.40	393.28	394.16	393.68	392.39	390.08	389.00	388.92	390.20	391.80

Seasonal variation in CO_2

Using your graph on the opposite page:

Which month has the highest CO_2 concentration .....

Which month has the lowest CO_2 concentration .....

Why do you see this annual fluctuation?

.....

.....

.....

.....

Graph title:

Homework 1: Baseline assessment

The purpose of this homework is to test your knowledge and skills so that you can build on them during this course. There are 2 sections.: The first follows on from work we did in the first tutorial, and the second section tests your skills with some challenging puzzles. These questions are deliberately designed to be challenging, so try to do as much as you can, but don't worry if you do not understand some of them!

Part 1: Short-term vs long-term trends

Using the graph paper opposite, plot the data for a 10-year period at Mauna Loa. You should plot 2 data points per year, one for each of the 2 months you identified during the last tutorial. These represent maximum and minimum CO_2. Use the data on the previous page

Describe what the long-term trend is in the graph you have drawn.

.....

.....

.....

.....

Explain what the reasons are for this trend?

.....

.....

.....

.....

Which RCP scenario do you think is most likely to happen and why?
What does your answer mean in terms of future climate change?

.....

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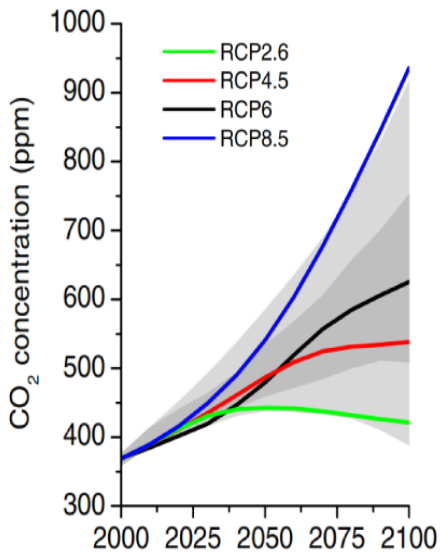


Atmospheric CO_2 concentration …….. At Mauna Loa

Visit the website where global atmospheric CO_2 data is recorded (www.co2.earth)

What is the CO_2 concentration today?

..... ppm on ..... (date)

What was the average CO_2 concentration last month?

..... ppm in ..... (month/year)

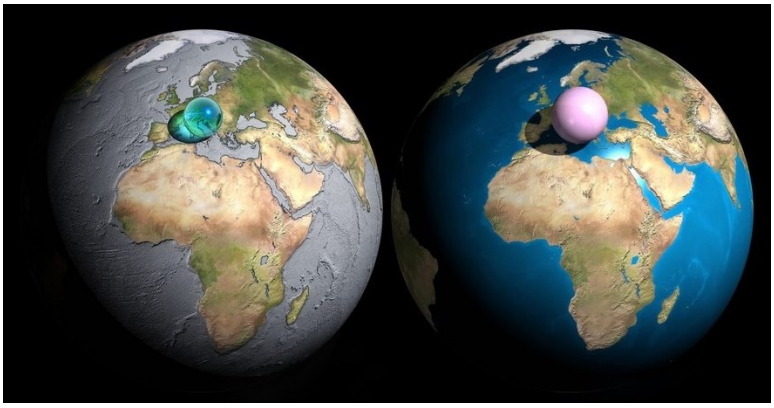
Use the conversion we practiced in the last tutorial to give these ppm CO_2 concentration values as percentages

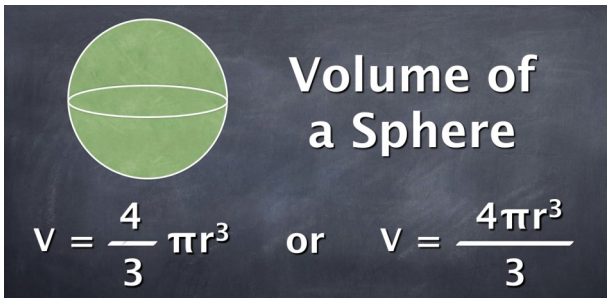
Today ..... % CO_2

Last month ..... % CO_2

The following questions relate to the paragraph and diagram below

"The picture below shows the total volume of water on Earth (left) and of air in the Earth's atmosphere (right) shown as spheres (blue and pink). The spheres show how finite water and air supplies are. The water sphere measures 1390 kilometres across and has a volume of 1.4 billion cubic kilometres. This includes all the water in the oceans, seas, ice caps, lakes and rivers as well as ground water, and that in the atmosphere. The air sphere measures 1999 kilometres across and weighs 5140 trillion tonnes (5.14×10^{15} tonnes). As the atmosphere extends from Earth it becomes less dense. Half of the air lies within the first 5 kilometres of the atmosphere. "





What volume is the atmosphere (pink) sphere?

..... km3

Calculate the volume and mass of CO_2 in the entire atmosphere?

..... km3 equivalent to m3

What is the molecular weight (Mr) of CO_2?
(There is a periodic table at the back of this booklet)

Mr = ...

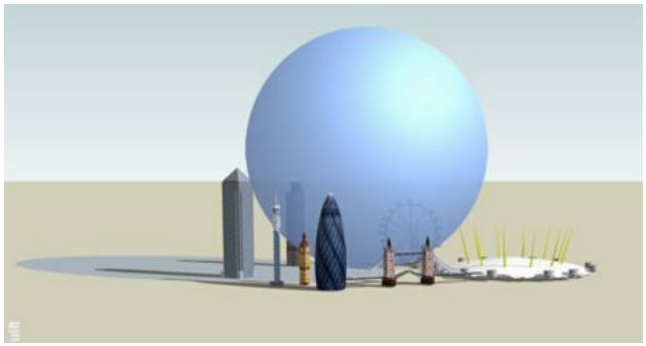
Using the values you calculated earlier, how many moles of CO_2 are there in the atmosphere?
Use standard form if appropriate

..... moles CO_2

How much CO_2 is within the first 5km of the atmosphere?

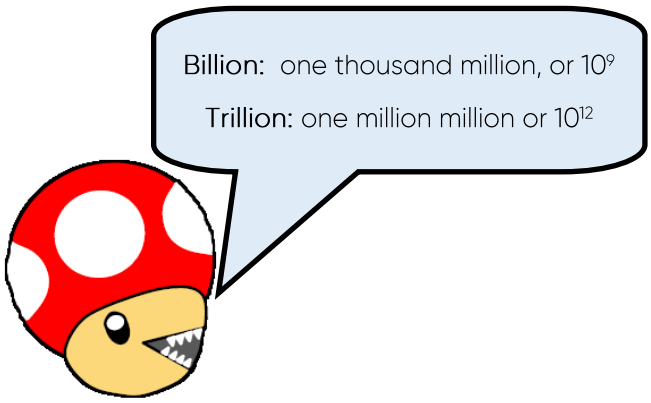
..... moles CO_2

Across the globe, roughly 80 million tons of the greenhouse gas are emitted every day by human activities.
London outputs 98,100 tonnes CO_2 daily, this is visualised in the picture below,



In 2014 , the total CO_2 emissions for the whole of the UK was 403,769,000 tonnes
What % of the total UK emissions are from London?

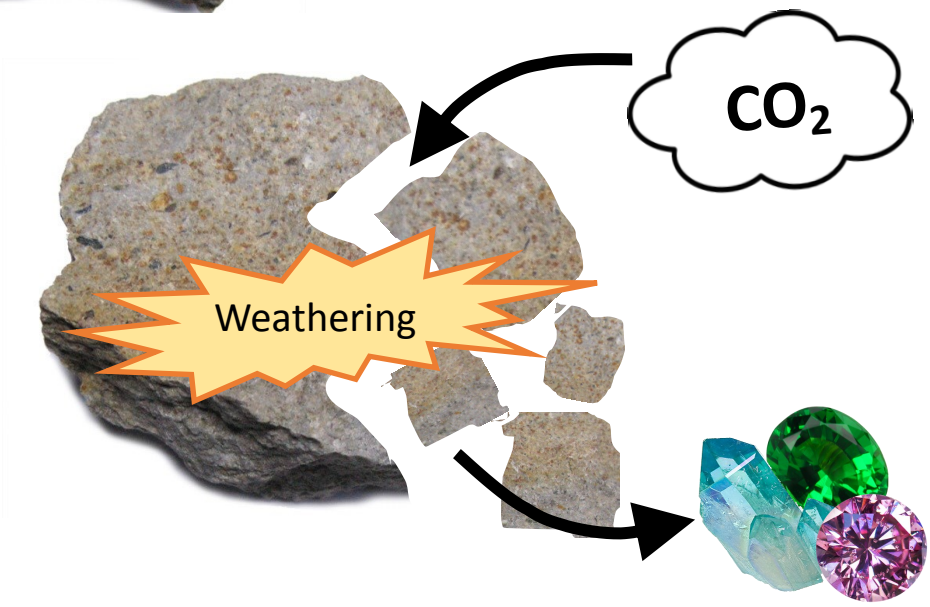
..... %



Tutorial 2– Rock Weathering

Rocks are made up of different minerals. These contain chemical elements that plants need to grow.

Chemical weathering of rocks uses up CO_2 and releases minerals which can later be taken up by plants



What is the Purpose of Tutorial 2?

- To understand the process of silicate rock weathering
- To be able to calculate CO_2 sequestered by rock weathering
- To know the major mineral nutrients required by plants

Activity 1: Find the words to complete the paragraph about weathering:

There are 3 main types of ....., physical , chemical and biological

..... weathering is the process of rocks breaking apart .....changing their chemical composition.

..... weathering is caused by rain water reacting with ..... in rocks to form new minerals (clays) and soluble salts.

Rain is mildly .....and it slowly eats away rocks. This is because ..... from the air reacts with water to form a chemical called ..... acid.

When plants or microbes break down rocks, the process is known as ..... weathering.

All living things need elements, such as ..... , ... and ..... in order to grow. These ..... are found within rocks. Plants and fungi attack rocks.

.....grow on rocks and release acids to ..... the minerals in them and release nutrients.

L	C	L	C	M	G	B	A	N	A	N	A	G	D	M
A	I	A	N	I	M	N	D	O	L	V	S	A	I	A
C	D	C	S	T	N	E	I	R	T	U	N	R	S	G
I	I	I	B	Y	V	O	B	R	R	K	F	L	S	N
S	C	G	H	Z	D	P	B	O	E	U	N	I	O	E
Y	A	O	H	X	Z	X	H	R	N	H	S	C	L	S
H	Z	L	X	R	U	P	Q	G	A	H	T	N	V	I
P	P	O	T	A	S	S	I	U	M	C	Q	A	E	U
E	D	I	X	O	I	D	N	O	B	R	A	C	E	M
K	G	B	H	C	H	E	M	I	C	A	L	J	I	W
Z	Z	P	U	H	S	I	F	T	U	O	H	T	I	W

Rock weathering chemistry

Balance the equations for silicate and carbonate rock weathering, and complete the statement about CO_2 sequestration.

..... rock weathering

...$CaSiO_3$ + ...CO_2 + ...H_2O → ...HCO_3... + Ca... + ...SiO_2

For every mole of CaSiO3 weathered, ... moles of CO_2 are sequestered

..... rock weathering

...$CaCO_3$ + ...CO_2 + ...H_2O → ...HCO... + ...Ca...

For every mole of CaCO3 weathered, ... moles of CO_2 are sequestered

Rock density

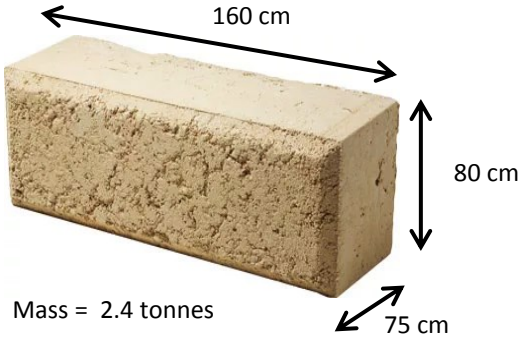
State the formula for density in words:

.....

What SI units does density have?

.....

You can use density to help you identify types of different rock.



In the space below, calculate the density of one of the blocks used to build the pyramids.
Using the table on the next page, suggest what type of rock were the pyramids made from?

Remember

$1m^3$ = ... cm^3

1 tonne = ... kg

Density: ..... (SI units please)

Rock type: .....

How much CO_2 does weathering sequester?

1. Calculate molar mass (Mr) for each of the minerals in the table below– put answers in column 4
2. Calculate the number of moles of each mineral in 1kg – put answers in column 5
3. Using your answers in column 3 and the density data in column 5, calculate the number of moles in 1m3 – Put answers in column 6

Rock type	Formula	Density (kg/m3)	Mr	Moles/kg	Moles/m3
Limestone	CaCO3	2500			
Dolomite	CaMgCO3	2900			
Wollastonite	CaSiO3	2800			
Olivine	MgFeSiO4	3300			

Look back at the equations for carbonate and silicate weathering on the previous page:
For each m3 of **wollastonite** (silicate) weathered, how much CO2 is sequestered?

..... moles CO_2 equivalent to ..... Kg CO_2

For each m3 of **limestone** (carbonate) weathered, how much CO2 is sequestered?

..... moles CO_2 equivalent to ..... Kg CO_2

Silicate weathering is a better long-term CO_2 sink than carbonate weathering. This is because, when the soluble ions ..... and ..... from carbonate weathering reach the oceans, they can re-form carbonates.

This process reverses the carbonate weathering reaction and releases CO2. However, because this process is so slow, taking 1000-10,000 years, we can still think of carbonate rock weathering as a CO2 sink.

Equation for carbonate deposition: .....

Shells , corals and some kinds of plankton (tiny sea organisms) are made from carbonates.

Homework: Carbon offsetting

Hope valley cement works in the Peak District produces 1 million tonnes of CO_2 every year. Using the information from last lesson, work out how many tonnes of wollastonite would need to weather in order to sequester all the CO_2 produced? this by following the steps below, and give your answer in tonnes.

1. How many moles of CO_2 are sequestered for every mole wollastonite?

1. Use the molar masses of CO_2 and wollastonite to work out the mass of wollastonite needed?

(Mr CO_2 = ...) (Mr $CaSiO_3$ = ...)

If the surface area of wollastonite exposed to weathering is 100 km2, how deep does the wollastonite need to weather in order to sequester this amount of CO_2. Calculate this by following the steps below, and your previous answers. Give your final answer in millimetres.

3. What volume of wollastonite is this equivalent to? (remember: use the density formula)

4. Calculate depth of wollastonite needed using volume and area

..... km deep is equivalent to ..... mm deep

In 2003, 7,000 trees were planted around Hope Cement Works to try to offset the production of carbon dioxide. The UK forestry commission estimates each young tree sequesters approximately 2 kg of CO_2 per year.

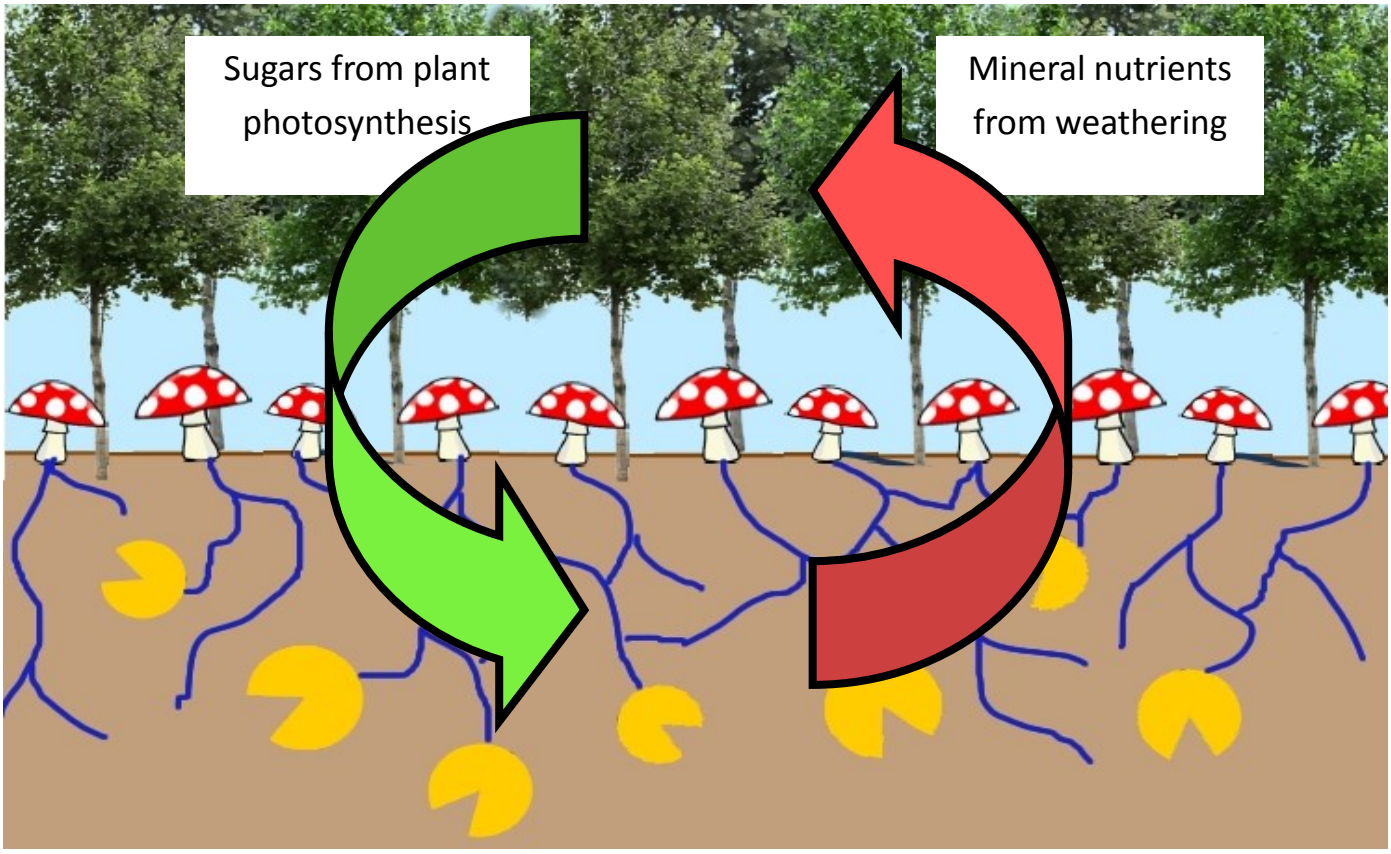
5. How much CO_2 is sequestered by the 7000 trees planted at Hope valley cement works?

..... kg CO2

6. How many trees would you need to plant to sequester ALL the CO_2 produced by Hope valley cement works?

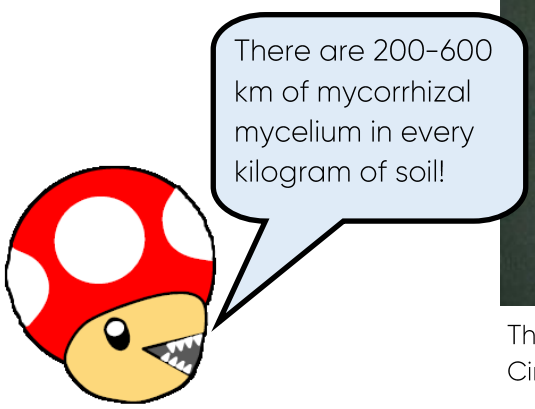
..... trees

Tutorial 3 – Why do mushrooms eat rocks?



What is the Purpose of Tutorial 3?

- To learn about mycorrhizal-plant symbiosis
- To understand why and how fungi promote mineral weathering
- To know the major mineral nutrients required by plants



The picture above shows a tree root covered in mycorrhizal fungi. Circle the fungal hyphae spreading out from the root

Fungi in the soil

Activity 1: Read the following passage and answer the questions below

Every teaspoon of soil contains more micro-organisms than there are people on Earth. Soil near the roots of plants is even more crowded, and there can be 1000-2000 times this number. This is because root secretions provide nutrition for these microorganisms.

Mycorrhizal fungi (mycorrhizas) are one kind of soil microorganism. These form a symbiosis with plant roots. Most trees, grasses, flowers, and crop plants depend on these mycorrhizal fungi for taking up soil nutrients.

Mycorrhizal fungi are very good at taking up soil nutrients. Mycorrhizas increase the absorbent surface area of roots by 100-1000 times. Fungal hyphae (root-like structures) are narrower than roots, so they can get inside soil pores and cracks where roots cannot fit and access nutrients hidden there.

Fungi can also increase the availability of soil nutrients by releasing secretions that increase rock weathering. Mycorrhizae can secrete weak acids, chelating compounds and enzymes. In exchange for supplying mineral nutrients to plants, mycorrhizal fungi gain carbohydrates (sugars) from their host plant roots. Plants use between 15-30% of their sugars from photosynthesis to feed these fungi.

What does symbiosis mean?

.....

.....

What are the costs and benefits to trees of hosting mycorrhizal fungi on their roots?

Benefits to plants	Costs to plants

Why are fungi so good at getting mineral nutrients from the soil?

.....

.....

.....

.....

.....

Mycorrhizal fungi under the microscope

If you wash plant roots and observe them under a microscope, it is possible to see mycorrhizal fungi. These are easier to see on some types of plant roots than on others. These is space below to draw a diagram or write a description of some plant roots you observe under the microscope.

.....

.....

.....

.....

.....

.....

Mineral nutrients

Rocks store many essential nutrients that plants need to grow. Phosphorus is one of the most important and used in many fertilisers. The chemical reactions that make rocks weather both sequester CO_2 and release mineral nutrients into solution.

Mineral deficiency is the situation where a plant cannot get enough of a particular mineral from the soil for healthy growth. Different minerals are needed for different reasons, so each one causes different symptoms of mineral deficiency.

What do plants use phosphorus for?

.....

.....

.....

Give 3 examples of other essential plant nutrients

..... , ... , ...

Mycorrhizal fungi increase weathering rate

We learned on the previous page that plants and their mycorrhizal fungi increase rock weathering rates through producing a variety of chemical and enzymatic secretions. **Rates of silicate rock weathering are increased up to 10 times by plants and their fungi.**

When the lettering was first carved on this gravestone, it was 5 mm deep., you measure it in 2017, it is 4mm deep.

How long ago did Mr. F. Guy die? ..... Years

Using the equation (**Speed** = **Distance/Time**), work out what the weathering rate of the granite gravestone is

..... mm/year

Shortly after you have made these measurements, the gravestone falls over and is quickly overgrown by plants and fungi. Vegetation cover increase weathering rates tenfold.

What is the new weathering rate of the granite?

..... mm/year

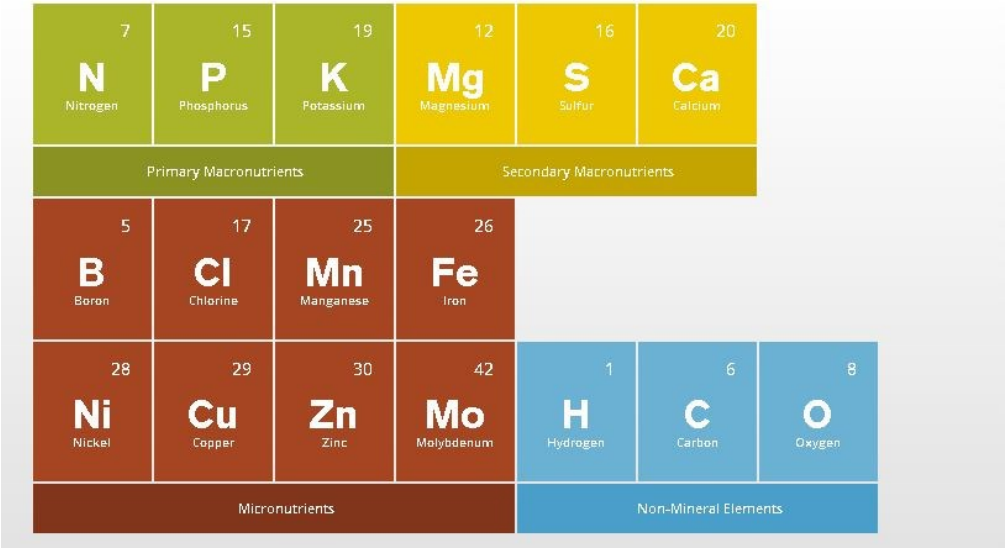
How long (at this new weathering rate) until the letters have completely disappeared?

..... years

Plant mineral nutrition

Periodic Table of Crop Nutrients

17 nutrients are essential for plant health. Optimal yields can only be produced when all these nutrients are in proper supply. According to the Law of Minimum, if one or more nutrients are lacking in the soil, crop yields will be reduced, even though an adequate amount of other elements is available.



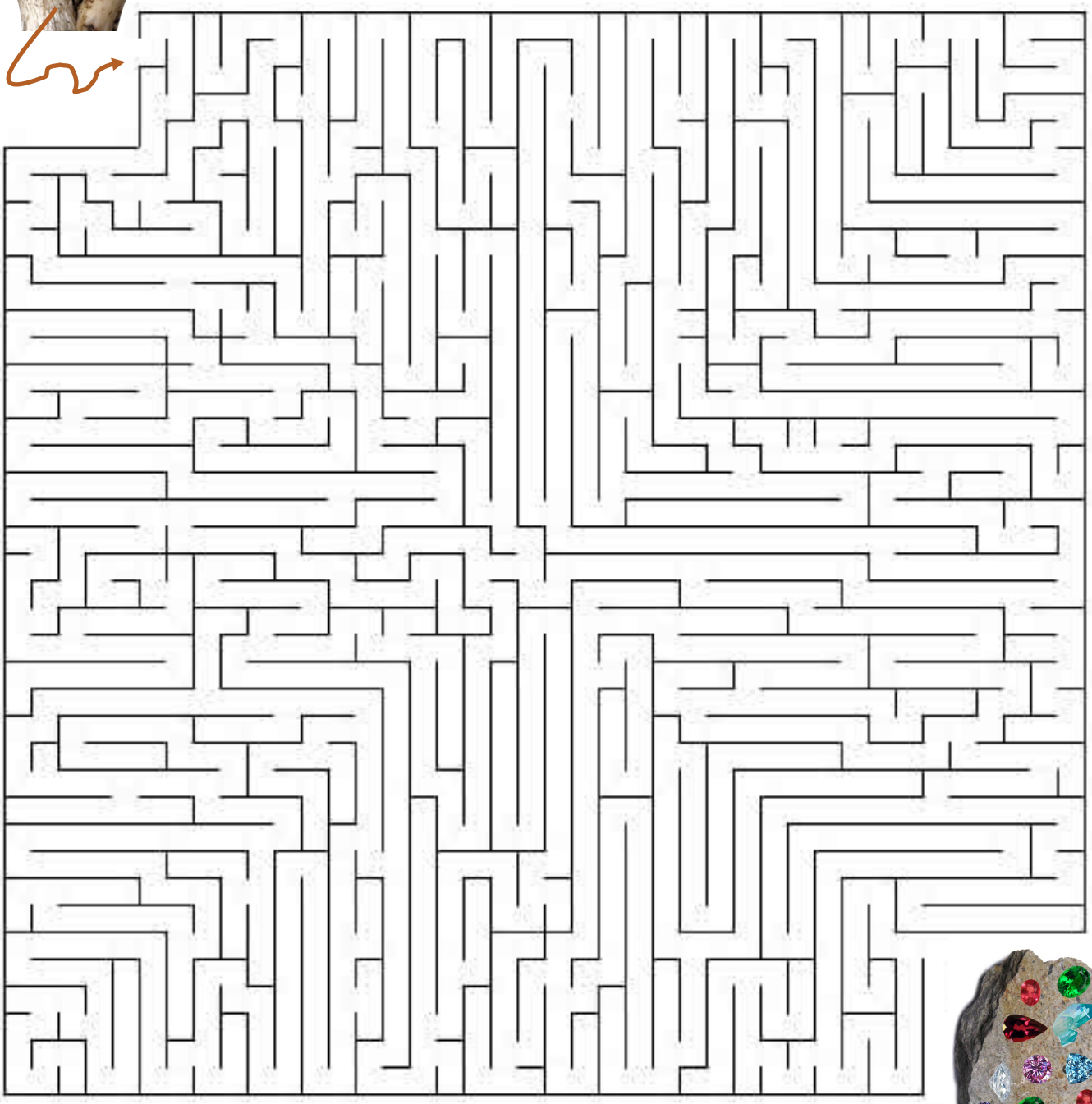
The 'periodic table of crop nutrients' shows nutrients essential for plant health. Use this website (http://www.cropnutrition.com/nutrient-knowledge) to find out about 3 more elements essential for plant nutrition. Fill in the table below with your findings.

Element	Plants use this for….	What does deficiency look like?

Mycorrhizal hyphae are really good at gathering nutrients because they are really narrow and can fit into soil pores and cracks that roots cannot reach.

Can you help the mycorrhizal fungal hypae reach the mineral nutrients!

Feel free to ignore this page ;-)

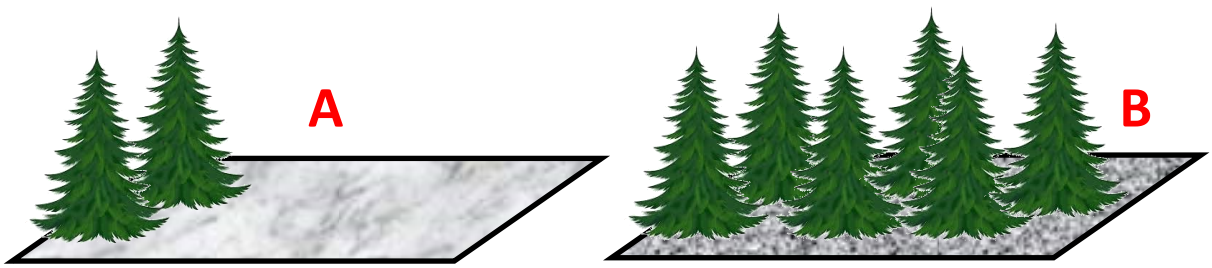


I have actually no idea how hard this maze is...

But if you manage to do all the homework AND help these sad little mushrooms, there may be a sweet prize in store next week!

Homework: How do plants and mycorrhizas affect CO_2 sequestration?

You are surveying the CO2 uptake of two different areas of land. They have different bedrock and different amounts of vegetation cover. Both areas measure 100 km2.



Area:	100 km^2	100km^2
Rock type:	Limestone (Mr = 100)	Wollastonite (Mr = 116)
Vegetation cover:	20 %	85 %

Without vegetation cover, wollastonite weathers at a rate of 0.009mm/year and limestone weathers at a rate of 0.018mm/year. Using information from tutorial 3, what are their weathering rates WITH vegetation cover?

Wollastonite ..... mm/year

Limestone ..... mm/year

What is the total volume and mass of limestone weathered in area A over 1 year? Remember to convert your measurements to metres before calculating. Use the **density data** from tutorial 2.
Carry out your calculation in two parts: WITH and WITHOUT tree cover, as these have different rates.

..... M3

..... Kg

Using the same method, what is the total volume, mass of wollastonite weathered in area B over 1 year?

..... M3

..... Kg

How many moles of limestone and wollastonite are these masses equivalent to? Molar masses are given on the previous page. Remember to consider your mass units when calculating.

..... Moles limestone

..... Moles wollastonite

Using the balanced weathering equations from tutorial 2, how many moles CO_2 are sequestered in areas A (limestone) and B (wollastonite)

..... Moles CO_2 sequestered by limestone (A)

..... Moles CO_2 sequestered by wollastonite

What is the TOTAL CO_2 consumption by both areas A and B (together) in 1 year? Give your answer in kg, using standard form if necessary.

..... Kg CO_2 / year

Which area, A or B, has the greatest overall CO_2 consumption (due to weathering only)?

.....

Use your findings to discuss how plants and mycorrhizal fungi affect CO_2 sequestration through weathering.

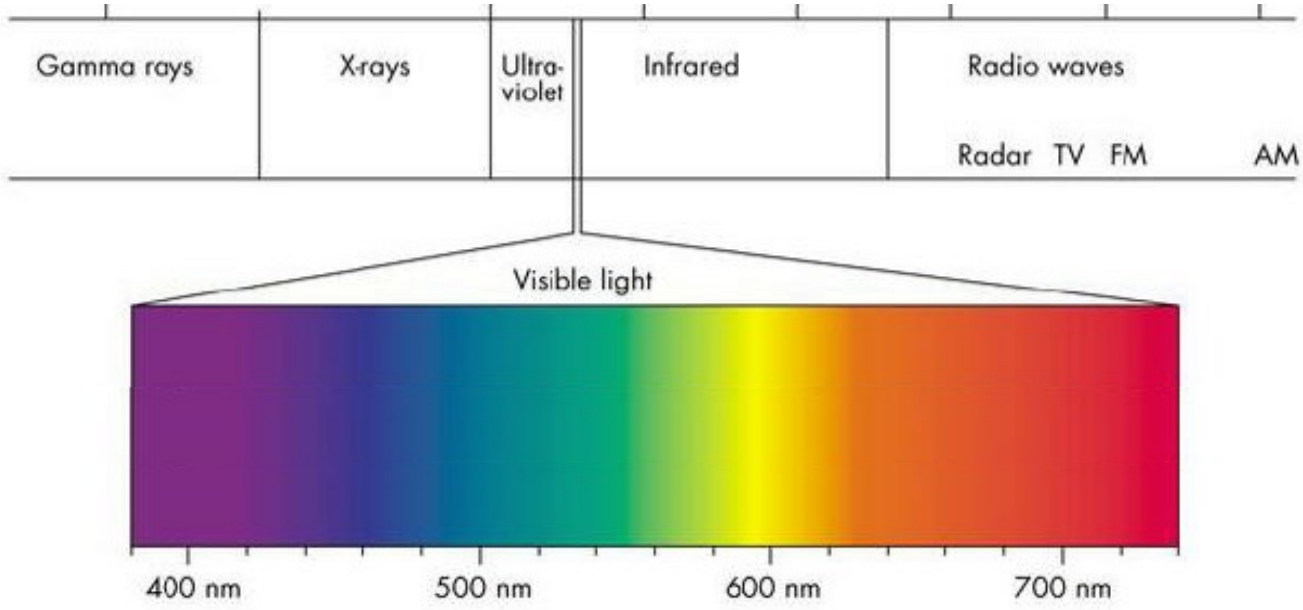
.....

.....

.....

.....

Tutorial 4 – Rock Fingerprints



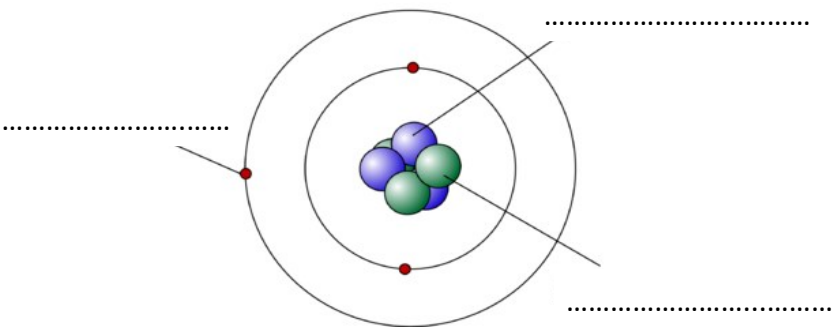
This diagram shows the electromagnetic (EM) spectrum

What is the Purpose of Tutorial 4?

- To learn how Atomic Emission spectroscopy (ICP-AES) works
- To understand the concept of trace elements in rocks
- To be able to interpret ICP-AES spectroscopic data and its use in forensics

Spectroscopy is the study of how electromagnetic radiation (or light) interacts with matter

Label the diagram with the names and charges of the 3 main types of particle that make up matter:



What is Atomic Emission Spectroscopy (ICP-AES)?

ICP-AES is probably the most versatile techniques in an analytical laboratory. Applications include: analysing water from sewage treatment plants, analysing meteorites, lunar rocks, soils, rocks and in forensics to help solve crimes.

Match up the questions on the left with the answers on the right to find out about spectroscopy

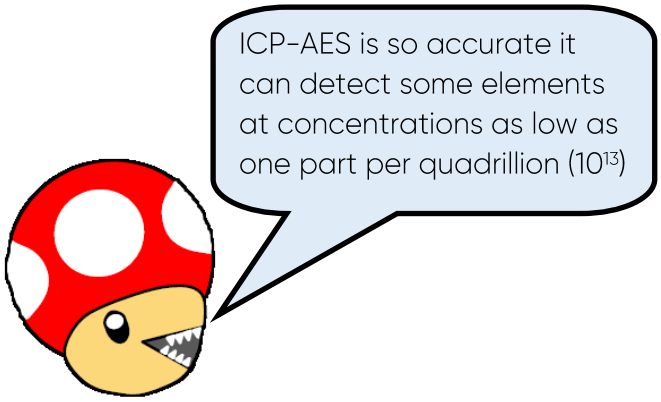
	Plasma is produced from argon gas and is roughly same temperature as the surface of the sun
What happens when EM radiation is absorbed by matter?	Separates all the different wavelengths and measures their strength
How is spectroscopy used to identify different elements?	Electrons are raised into higher energy levels,. When they return to their original, lower energy levels, this releases EM radiation.
What must you do to a sample in order to do ICP-AES analysis?	Ionized gas with free electrons and positive ions at high temperatures.
What is a plasma?	All the different elements in a substance give it a unique pattern of EM wavelengths emitted. This gives each substance a 'fingerprint'.
What is the plasma in ICP-AES like?	Ionise the sample by producing a plasma
What does a spectrometer do?	Different atoms absorb and produce EM radiation (light) at characteristic wavelengths. This is like when you see different colour light when you do a flame test
How can ICP-AES be used in forensic analysis?	

ICP-MS is used for forensic geochemistry

One of the major advantages of ICP-AES is that it is both very accurate and very rapid. ICP-AES can determine concentrations of 50 elements simultaneously. Not every element can be detected by ICP-AES, so there may be a 'missing percentage' when looking at mass data for elements in a sample.

The determination portion of the process takes approximately 2 minutes to complete.

How many samples could chemist analyse in a week if she works from 9am-5pm Monday to Friday?
How many individual elemental analyses would have been performed in this time?



..... Samples

..... Elemental analyses

Murder in Sheffield

Last night there was a horrible murder in Weston Park. You are the police detective in charge of investigating this case. You have apprehended a man called Ben who has mud on his shoes. You suspect that he was in the park last night, however, he claims to have been playing football in Crosspool.
You have sent the shoes and some soil samples from both Weston park and Crosspool to the forensics lab for analysis by ICP-AES.

Your forensics lab reports that the mud on the shoe contained microscopic grains of the mineral olivine ($MgFeSiO_4$) , a common component of some volcanic rocks such as basalt.

Is olivine a silicate or a carbonate?

.....

What is the molar mass (Mr) of olivine?

.....

Complete the table of mass percentages of the different elements in olivine. Remember, the sum of all mass percentages should be 100%.

Element	Working out	Mass %

What is the ratio of magnesium:iron in olivine?

.....

You have received the forensic report on the 2 soil samples. These are shown in the table below. Unfortunately, the forensic scientists have forgotton to label the data table with the elements, and have only included the wavelengths of absorption. Match up the wavelengths of absorption with the appropriate element symbols in the data table below. (Use the periodic table of ICP-AES wavelengths at the back)

Emission wavelength (nm)	766.49	393.37	396.15	213.62	238.20	589.59	257.61	407.77	280.27
Element									
Weston Park	7.0	10.2	13.1	2.2	1.6	9.0	1.1	1.5	13.9
Crosspool	8.7	12.0	12.9	3.0	11.5	10.1	0.7	2.1	4.8

Why do the mass percentages of these elements in soil not add up to 100%

.....

.....

.....

Use your Mg:Fe ratio to decide which soil sample may contain **traces** of olivine.

.....

.....

.....

If all magnesium in the soil sample you identified above is present as olivine minerals. What is the total mass of olivine in 1kg of soil?

..... g olivine / kg soil

Should you let Ben go?

.....

Explain your answer

.....

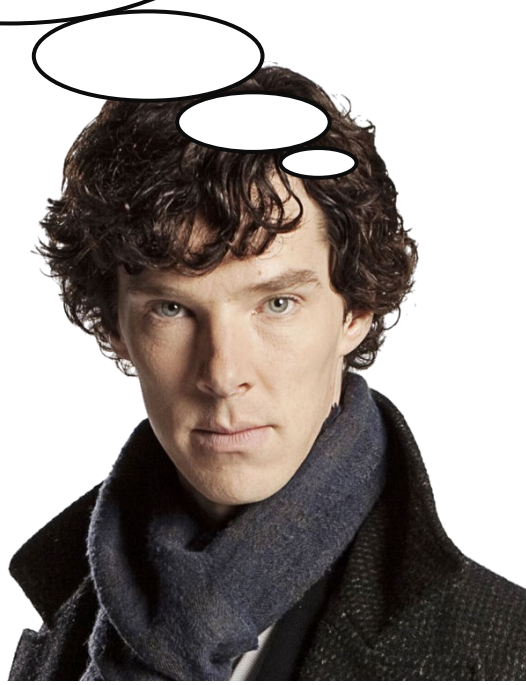
.....

.....

.....

.....

.....



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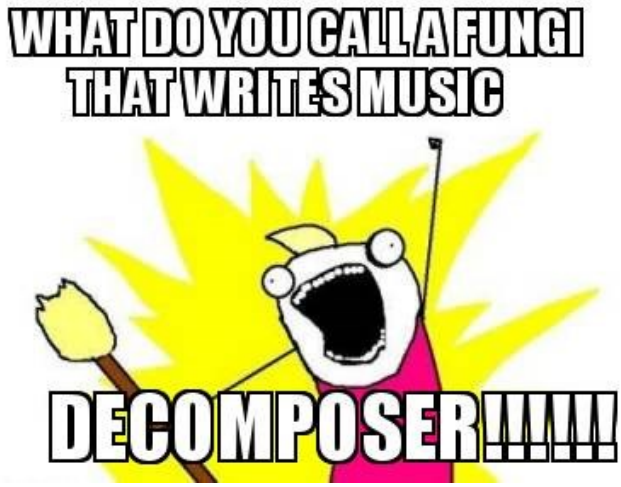
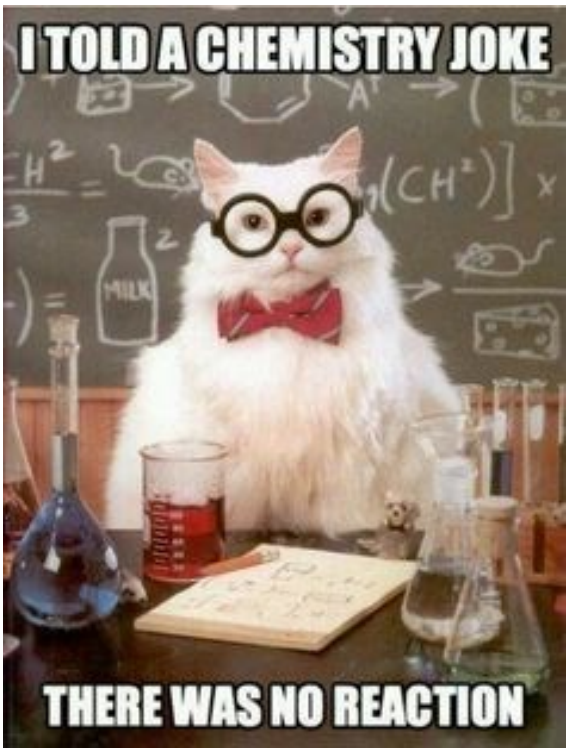
Except for some terrible mushroom jokes I found online ;)





Homework: Roundup of tutorials 1-4

As we've completed 4 tutorials now, this homework is about looking back over what we have been learning. This is in preparation for tutorial 5 where we're going to bring together ideas from all 4 of these tutorials.

1. Choose 4 new words you have learnt in these tutorials and write a definition for each of them in your own words:

Word	Definition

2. Think about the key information and skills you have learnt in each tutorial and write a 1-2 sentence summary of each one:

- .....
  .....
  .....
- .....
  .....
  .....
- .....
  .....
  .....
- .....
  .....
  .....

Tutorial 5 – Can we put science in a box?

What is the Purpose of Tutorial 5?

- To understand the concept of interdisciplinary research
- To write a summary of this course that could be later used in a university personal statement
- To bring together knowledge and skills from tutorials 1-4 in order to complete complex calculations

Taboo

Level 1: In pairs describe each of the 4 words you identified for homework. Your partner must guess what word you are describing.

Level 2: As a group, decide on some words that you cannot use when describing.
Write these down below (eg. You cannot say the word 'rock'):

What does interdisciplinary mean?

A) The many strategies for maintaining discipline

B) Stressing one branch of knowledge more than others

C) Relating to more than one branch of knowledge

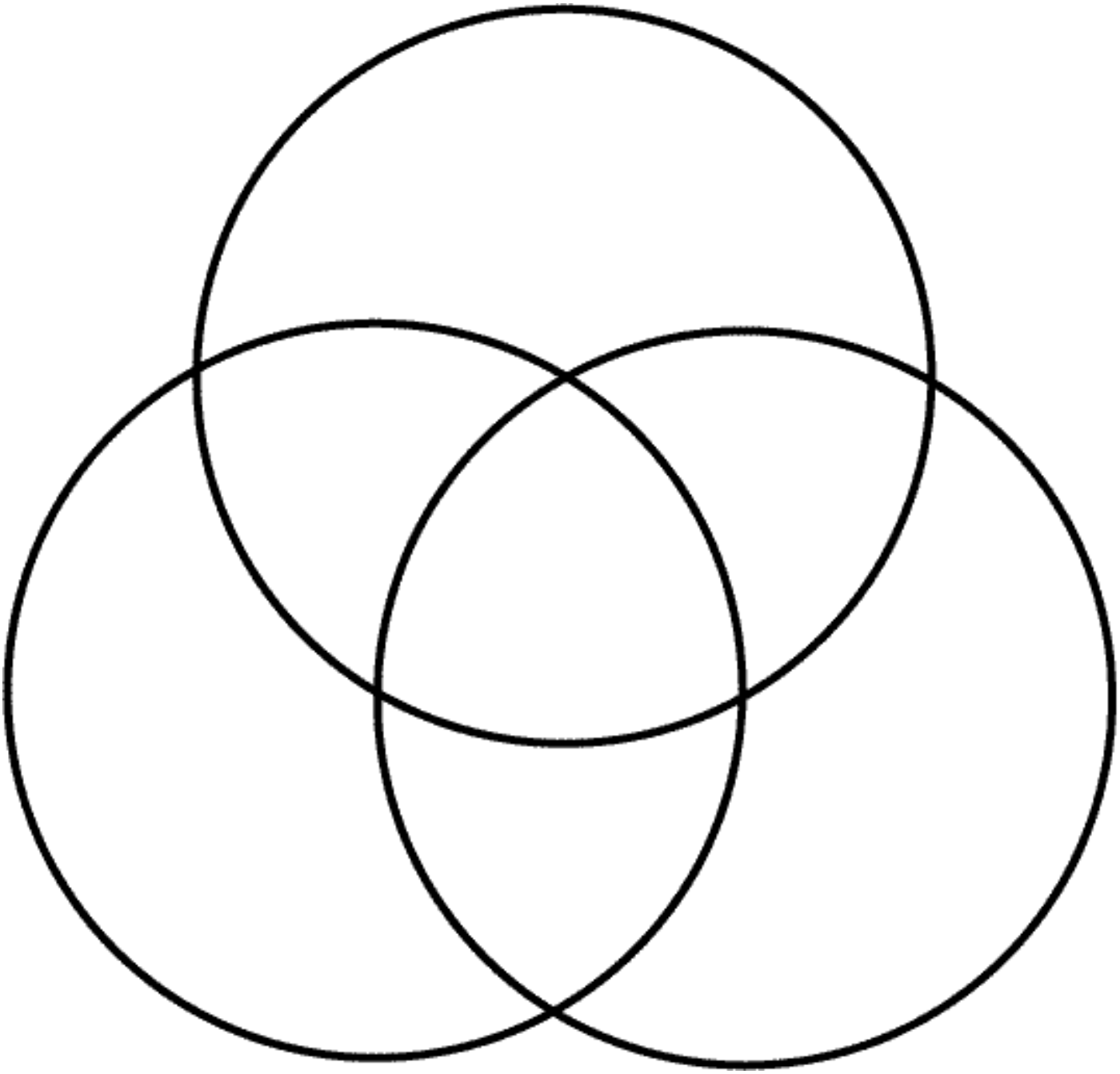
D) Using any form of discipline in the classroom

E) In a maths class, teaching multiplication and division

Interdisciplinary Venn diagram

Label the categories of the Venn diagram, then fill in each section with different things we have learned over the last 4 tutorials. You can use the key points you identified for homework to help you, as well as thinking of new ideas with your group.

.....



....

Uni personal statement—ideas

If you decide to apply to university whilst you're in Sixth Form, you will need to write a 'personal statement'. This is basically your chance to tell the university you want to go to how brilliant you are and how interested you are in studying there.

One thing that will really impress interviewers is that you've already been doing university-level work whilst doing this course… in year 10!
But… they won't know what it is or what you've done unless you tell them.

The space below is for you to jot down ideas or words that you'd like to include in your statement. You can use your Venn diagrams and the key points yiou came up with in your last homework assignment.

I've written a few words to get you started:

Inspired me to learn more about….

6-week university-level course

Interdisciplinary

Cutting edge research in …….

Uni personal statement—writing

Now you've had lots of ideas, have a go at writing a paragraph about: What the course was , what you've been learning or doing, and how this links to your personal interests/inspirations.

Don't worry if you don't like your first attempt, there's another space at the bottom of the page for a second try :) it usually take more than one attempt before you're happy with this kind of statement!

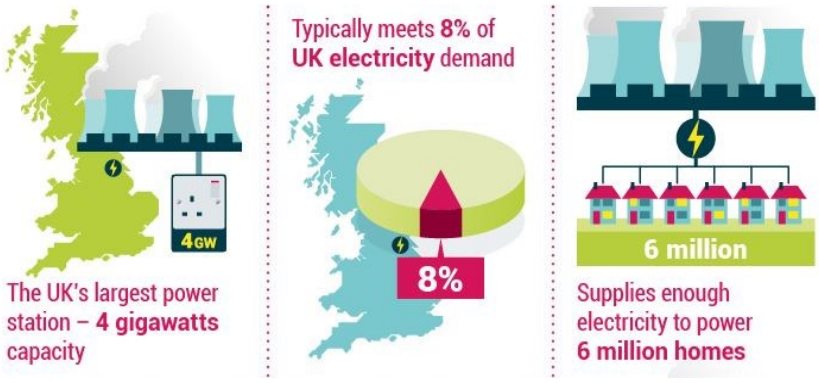
Final Assignment

The aim of this assignment is to test the knowledge and skills you have learned over the last 5 tutorials. The style of questions is similar to those you have completed in tutorials and for homework, however, this time you get fewer prompts to help you through each calculation. If you get stuck, try to break down each calculation into simple steps. Look back at your previous work to see ways you can do this.

CO_2 production at Drax power station—Assignment Part 1

You are employed by an environmental consultancy, and have been tasked to do make an assessment of a possible carbon-offseting scheme at Drax power station outside Doncaster. Drax power station is the second largest coal-fuelled power station in Europe and because of its large size, it is the UK's single largest emitter of carbon dioxide. This has made Drax the focus for CO2 emissions reduction.

Over the last decade, Drax's emissions have been reduced dramatically by switching fuel type. Instead of burning only coal, Drax also burns biomass, which is a lot less polluting. Biomass is organic material obtained from living or recently living plant matter that can be burnt to produce energy. The materials that Drax uses include low grade wood, such as forest thinnings, tree tops and branches as well as sawmill residues, and to a lesser extent residual agricultural products, such as straw, sunflower and peanut husks.



Statistics about Drax power generation

- Electricity generation from coal has emissions of 2.42kg CO_2 for every tonne of coal burned.
- Electricity generation from biomass has emissions of 0.8kg CO_2 for every tonne of biomass burned.
- In 2016, 7.7 million tonnes of coal were burned at Drax. The total emissions were 22,800,000 tonnes CO_2.
- Coal is transported to Drax by rail. The capacity of a single coal hopper wagon is 52m^3.
- The average density of coal is 1400kg/m^3 .

CO_2 production at Drax power station—Assignment Part 1

Your first task is to asses the CO_2 emissions from electricity generation at the site.
Include in your answer:

- What mass of biomass was burned? Give your answer in tonnes of biomass
- What is the CO_2 emissions reduction by burning biomass compared to burning ONLY coal? Give your answer in tonnes of CO_2
- How many coal hopper wagons are needed every day to keep Drax supplied with coal

You may provide your answers in this booklet , or on an additional sheet, along with the second part of this assignment.

CO_2 offsetting by weathering at Drax

Drax hopes to increase its carbon offsetting potential through weathering by planting trees across either site A or site B. **6km² of forest can be planted of site A, and 6km² can be planted on site B.** Tutorial 3 taught us that: rates of silicate rock weathering are increased 10 times by plants and their mycorrhizal fungi.

The two rock samples A and B represent the geology of the areas marked on the map below. ICP-AES data is available for 2 rock samples taken from the points marked on the map. This data has not yet been processed to identify the geology at each site. A survey of local geology has shown that the only 3 possibilities for minerals in the bedrock around Drax are:

- K-feldspar ($KAlSi_3O_8$), a common mineral present in granite
- Calcite ($CaCO_3$), the main constituent of marble
- Olivine ($MgFeSiO_4$), the main constituent of basalt

The rock in area A weathers by 1.03 mm/year and area B weathers at 0.85 mm/year

Area A to the west of the main Drax site measures 17.3 km2 and area B to the East measures 15.8 km2

Emission wavelength (nm)	334.94	396.15	280.27	766.49	213.62	238.20	257.61	393.37	589.59
Element									
A).....	0.3	6.6	12.3	2.1	0.5	14.6	0.1	2.2	1.0
B).....	0.9	17.2	1.6	15.3	0.3	5.7	0.2	3.4	4.8

Basalt
3.0 tonnes/m3

Marble
2.7 tonnes/m3

Granite
2.8 tonnes/m3

CO_2 offsetting by weathering at Drax—Assignment part 2

One possibility to further reduce emissions at Drax is to offset CO_2 production through planting forests to increase rock weathering. You are an environmental consultant, tasked with writing an article to explain to Drax employees the benefits of tree-planting. You should describe how tree planting can offset CO_2 emissions, and to explain how you plan to assess the potential of this tree planting scheme.

In the **first part of your article,** you should explain:

- Why carbon offsetting schemes are required, referring to possible RCP scenarios
- What is the role of rock weathering in sequestering CO_2
- Describe the process of rock weathering by carbonic acid, and how the CO_2 sequestration potential differs for carbonate and silicate rocks.
- Explain how your proposed tree planting scheme will offset CO_2, including reference to mycorrhizal fungi
- What information will you require for your calculations in order to select a site for tree planting to maximise possible CO_2 sequestration
- What scientific techniques will you use to gather this information and how do they work?

In the **second part of your article,** propose a site (A or B) at Drax for your carbon offsetting scheme You must refer to the data contained on the previous pages and perform calculations to justify your choice.

Include in this section:

- Full details of any calculations, and a description of what you are trying to calculate.
- Using your skills in mole calculations, calculate how much CO_2 is consumed by sites A and B over a 1-year period both with and without tree planting? Remember to identify the geology of site A and B and to refer to the weathering equations and the rock density. Give your answers in tonnes CO_2/year.
- How much will the proposed tree planting scheme increase CO_2 consumption through weathering for site A and site B? Give your answer as a percentage of the total original CO_2 uptake without extra tree planting.
- What percentage of the total emissions of Drax are sequestered by weathering, at both sites A and B, with and without tree planting?
- Which site, A or B, has the greatest potential for CO_2 sequestration and why?
- How could Drax further reduce its net CO_2 emissions ('Net' emissions takes into account total CO_2 produced minus total CO_2 sequestered)?

Use appropriate headings and sub-headings to organise your work. Include any relevant diagrams , calculations and references to information you have read elsewhere (outside this booklet).

Your final submission should be word-processed and **1500-2000 words** long, including references. If necessary, provide any hand-written calculations on additional paper.

Weathering equations for 3 mineral types

Feldspar weathering

.....$KAlSi_3O_8$ + ...H..... + ...H_2O → .....$Al_2Si_2O_5(OH)_4$ + ...K..... + ...SiO_2

Calcite weathering

.....$CaCO_3$ + ...CO_2 + ...H_2O → .....HCO_3..... + ...Ca.....

Olivine weathering

.....$MgFeSiO_4$+ .....H_2CO_3 —> .....Mg..... + ...Fe..... + ...HCO_3..... + ...H_4SiO_4

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.

To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well…	What I could have improved on…

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?

What did you find challenging about the programme?	How did you overcome these challenges?

My target for future work is...

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

It gives credit to the authors of any sources you have referred to or been influenced by.
It supports the arguments you make in your assignments.
It demonstrates the variety of sources you have used.
It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

Quote directly from another source.
Summarise or rephrase another piece of work.
Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. **A marker in your assignment:** After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].

2. **Bibliography:** This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

Websites – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

Books – Author, date published, title of book (in italics), pages where the information came from.

E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

Articles – Author, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), date of the article.

E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', Guardian, 10 July 2014.

Appendix 2 – Using the VLE

VLE username	
VLE password	

Please remember the following key details:

You are able log into the VLE either through the link on our website (www.thebrilliantclub.org) or going directly to the VLE site at (https://portal.thebrilliantclub.org/sign-in).

- Please update your profile with your full name and email address- this will allow you to retrieve forgotten passwords or usernames

If you forget your log-in details you can request them to be emailed to you by clicking the link on the VLE home page. (If you are still having problems you can email: schools@thebrilliantclub.org)

What is the VLE?

The VLE is a virtual learning environment for all pupils on Uni Pathways it is used for:

messaging your tutor

submitting homework

submitting your final assignment

accessing resources for your tutorials

finding out more information about university and careers

How should I use the VLE?

The VLE is a professional academic environment in which pupils are able to message their PhD Tutor. Here are a few things to consider:

Ensure you keep a professional tone in the messages you send to your tutors.

Ensure you always reply to your tutors in a timely manner.

Thank your tutor for the effort they are putting in to give you your feedback etc.

Submit all homework to your tutor on time.

IMPORTANT: Final assignment

- When you submit your final assignment, please remember that you need to do so through the 'My Activities' tab and not as an attachment to a message.

Notes

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Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 84.798
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

ICP-AES periodic table of wavelengths

This periodic table gives the wavelength that each element emits electromagnetic radiation following excitation during ICP-AES analysis.

This is intended to accompany tutorial 4.

Detection Limit Ranges
- < 0.1 ppb
- 0.1-1 ppb
- 1-10 ppb
- > 10 ppb

Wavelength (nm)

Ionization States
I = Neutral Atom
II = +1 ion

51 Sb — Atomic Number, Element
206.836 — Wavelength
I — Ionization States

1 H																	2 He
3 Li 670.784 I	4 Be 313.107 II											5 B 249.772 I	6 C 193.030 I	7 N	8 O	9 F	10 Ne
11 Na 589.592 I	12 Mg 280.271 II											13 Al 396.153 I	14 Si 251.611 I	15 P 213.617 I	16 S 180.669 I	17 Cl 725.670 I	18 Ar
19 K 766.490 I	20 Ca 393.366 II	21 Sc 361.383 II	22 Ti 334.940 II	23 V 290.880 I	24 Cr 267.716 II	25 Mn 257.610 II	26 Fe 238.204 II	27 Co 228.616 II	28 Ni 231.604 II	29 Cu 327.393 I	30 Zn 206.200 II	31 Ga 417.206 I	32 Ge 265.118 I	33 As 188.979 I	34 Se 196.026 I	35 Br 863.866 I	36 Kr
37 Rb 780.023 I	38 Sr 407.771 II	39 Y 371.029 I	40 Zr 343.823 II	41 Nb 309.418 II	42 Mo 202.031 II	43 Tc 249.677 II	44 Ru 240.272 II	45 Rh 343.489 I	46 Pd 340.458 I	47 Ag 328.068 I	48 Cd 228.804 I	49 In 230.606 I	50 Sn 189.927 II	51 Sb 206.836 I	52 Te 214.281 I	53 I 178.215 I	54 Xe
55 Cs 455.531 I	56 Ba 455.403 II	57 La 408.672 II	72 Hf 264.141 II	73 Ta 226.230 II	74 W 207.912 II	75 Re 197.248 I	76 Os 228.226 II	77 Ir 224.268 II	78 Pt 214.423 I	79 Au 267.595 I	80 Hg 194.168 II	81 Tl 190.801 II	82 Pb 220.353 II	83 Bi 223.06 I	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac															

58 Ce 413.764 II	59 Pr 414.311 II	60 Nd 406.109 II	61 Pm	62 Sm 442.434 II	63 Eu 381.967 II	64 Gd 342.247 II	65 Tb 350.917 II	66 Dy 353.170 I	67 Ho 345.600 II	68 Er 337.271 II	69 Tm 313.126 II	70 Yb 328.937 II	71 Lu 261.542 II
90 Th 283.730 II	91 Pa 385.958 II	92 U 385.958 II	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

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