



# Year 11 Chemistry

## Excursion workbook

### Your visit to ANSTO

At the Discovery Centre, you will:

- Collect data during a demonstration of a radiation experiment, using low level radioactive sources and radiation detection equipment.
- Observe background radiation in our cloud chamber

On site, you will visit:

- The OPAL (Open Pool Australian Lightwater) Research Reactor
- The Australian Centre for Neutron Scattering
- The Centre for Accelerator Science

The tour will conclude at the Discovery Centre. We have a number of brochures that you may wish to collect or they can be accessed on our website.

## Year 11 Chemistry: Nuclear Science Depth Study

We recommend that this excursion becomes the starting point for a nuclear science depth study. ANSTO's Year 11 Chemistry excursion helps students cover the following syllabus content:

### Module 1: Properties and structure of matter

Students:

- investigate the basic structure of stable and unstable isotopes by examining:
  - their position in the periodic table
  - the distribution of electrons, protons and neutrons in the atom
  - representation of the symbol, atomic number and mass number (nucleon number)
- calculate the relative atomic mass from isotopic composition
- investigate the properties of unstable isotopes using natural and human-made radioisotopes as examples, including but not limited to:
  - types of radiation
  - types of balanced nuclear reactions

### Working Scientifically

- Questioning and predicting
- Planning investigations
- Conducting investigations

We recommend students use our *Year 11 Chemistry Depth Study Guide* for ideas and resources for depth study activities after their excursion.

### NESA requirements for Depth Studies

- A minimum of 15 hours of in-class time is allocated in both Year 11 and Year 12
- At least one depth study must be included in both Year 11 and Year 12
- The two Working Scientifically outcomes of Questioning and Predicting, and Communicating must be addressed in both Year 11 and Year 12
- A minimum of two additional Working Scientifically skills outcomes, and further development of at least one Knowledge and Understanding outcome, are to be addressed in all depth studies.

## Pre Tour Questions

We expect students to have completed this pre-work prior to attending the tour. It consists of questions on concepts from junior years that are essential to an understanding of the nuclear science to be covered in the tour.

### Question 1

Atoms are made up of 3 sub-atomic particles: protons, neutrons and electrons. Choose options from the following lists to complete the table:

in nucleus	negligible	0
surrounding the nucleus	1	+1
in nucleus	1	-1

↓
↓
↓

Particle	Location	Mass in atomic mass units (amu)	Charge
Proton			
Neutron			
Electron			

### Nuclear Facts To Remember:

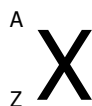
1. The number of protons in an atom is the **atomic number (Z)**.
2. The number of protons plus neutrons is the **mass number (A)**.
3. In a neutral atom, the number of protons and number of electrons are equal.

The atomic number, Z, determines what element the atom is, for example:

Z = 1, atom is hydrogen, symbol H

Z = 6, atom is carbon, symbol C

The notation for representing an atom is as follows:



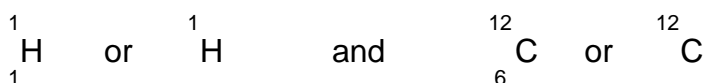
X = symbol of element

A = number of (protons + neutrons)

Z = number of protons

As the symbol or the Z-number uniquely identifies the element, only one of these **must** be present.

When naming atoms, we use the name or symbol of the element, followed by the mass number. For example: hydrogen-1 (or H-1) and carbon-12 (or C-12). The notation for these is:



## Question 2

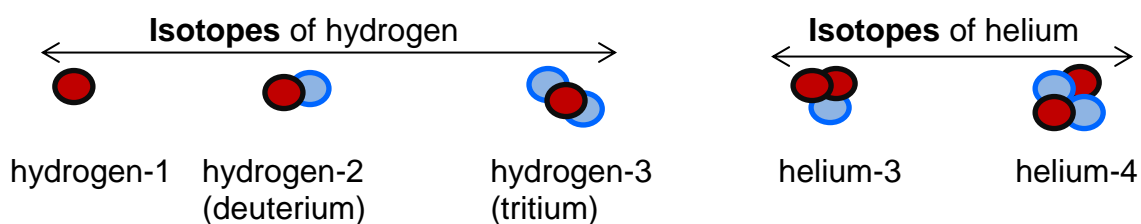
Use the online Atom Builder program (<https://www.ansto.gov.au/education/apps>) and the Periodic Table poster (<https://www.ansto.gov.au/education/resources/posters>) to help complete the table.

Name of atom	Number of protons	Number of neutrons	Mass number	Notation
nitrogen-14				
	3		7	
				${}^{19}_{9}\text{F}$
		14	27	

## Isotopes of Elements

The nuclei for the five smallest atoms and their names are shown in the diagram below. Nearly all atoms contain protons and neutrons. The hydrogen atom, hydrogen-1, is the only atom that does not contain neutrons.

**Key:**  proton  neutron



## Question 3

Using the information above, define the term 'isotope'

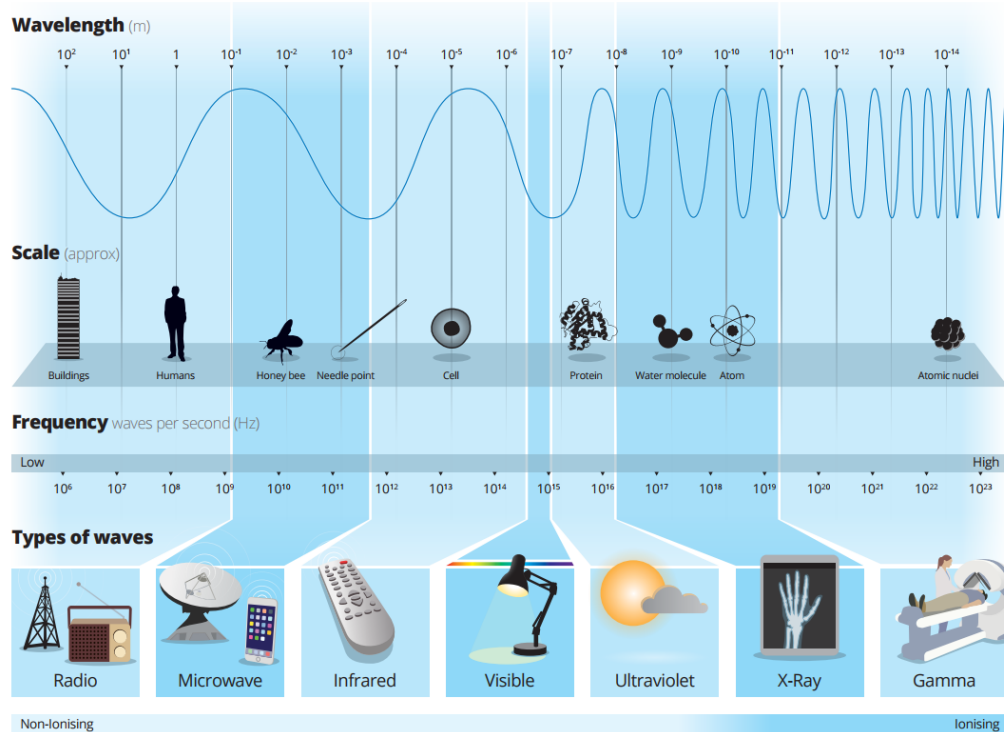
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## Electromagnetic spectrum

The electromagnetic spectrum below shows that radiation occurs in waves. The type of radiation depends on the amount of energy it has. Gamma rays are at the high energy end of the spectrum whilst radio waves are at the low energy end.



### Question 4

Refer to the ANSTO Electromagnetic Spectrum poster (shown above and also at <https://www.ansto.gov.au/education/resources/posters>) to complete the activity below:

Delete the incorrect terms in the following sentences.

The shorter the wavelength, the greater/lower the energy. Therefore ultraviolet radiation has more/less energy than infrared radiation but more/less than gamma rays.

## **Nuclear Radiation – Radioactivity**

In 1896 French scientist Henri Becquerel discovered a new kind of invisible radiation that seemed to be emitted from a uranium-rich rock. This radiation could not be stopped, increased or decreased. This was nuclear radiation and it was something completely new to science.

Marie Curie, working in Paris, coined the term 'radioactivity' to describe this new property, and discovered three new radioactive elements.

It is the structure of the nucleus of an atom that determines whether it is **radioactive**, or in other words, unstable. Unstable atoms undergo **radioactive decay**.

Further studies by New Zealander Ernest Rutherford showed that there are three different types of radioactivity. He named them after the first 3 letters of the Greek alphabet: alpha ( $\alpha$ ), beta ( $\beta$ ) and gamma ( $\gamma$ ) radiation.

### ***Alpha radiation ( $\alpha$ )***

Strong nuclear forces normally hold the protons and neutrons inside a nucleus together. But if the nucleus is too big, it will begin to break down and release an alpha particle.

An alpha particle is made up of two protons and two neutrons, has a charge of +2, and is identical to a helium nucleus.

Alpha particles have high energy when they are first released but quickly lose energy as they strike matter. Because alpha particles are relatively large, they have a low penetrating ability. They only travel a few centimetres through air and can be stopped by a sheet of paper or the outer layer of dead skin.

### ***Beta radiation ( $\beta$ )***

Nuclei are made up of protons and neutrons. If a nucleus contains too many neutrons, one of the neutrons will break down. A neutron breaks down to form a proton (which stays in the nucleus) and an electron (which is emitted as a beta particle).

Beta particles have a charge of -1, are much smaller than alpha particles, and have a higher penetrating ability. Beta particles can pass through skin but can be stopped by a small thickness of aluminium or plastic.

### ***Gamma radiation ( $\gamma$ )***

Sometimes a nucleus is still unstable after emitting an alpha or a beta particle and balances itself by releasing a burst of energy in the form of a gamma ray.

Gamma radiation consists not of particles but of energy in the form of extremely high-frequency electromagnetic waves.

Gamma radiation has the highest penetrating ability of all nuclear radiation. A thick layer of lead, concrete or several meters of water is needed to stop it.

### Question 5

After reading the information above, complete the following table for the three types of radioactive decay.

Name	Symbol	Consists of	Charge	Stopped by
Alpha	$\alpha$	Two protons and two neutrons (Helium-4 nucleus)		
Beta	$\beta$			
Gamma	$\gamma$		0	

Radioactive atoms, called **radioisotopes**, may emit only one type of radiation but it is more common for an alpha or beta decay to be accompanied by a gamma emission.

### Question 6

Isotopes are unstable if:

- They have too few neutrons
- They have too many neutrons
- Their nucleus is too large

Use the ANSTO periodic table

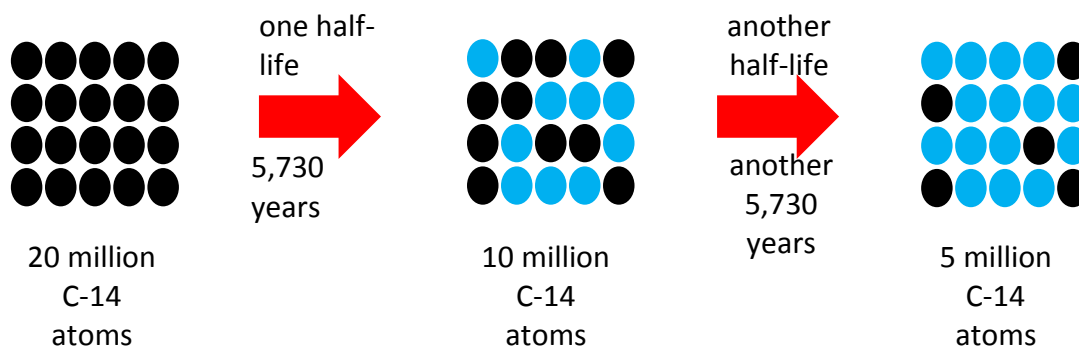
(<https://www.ansto.gov.au/education/resources/posters>) to identify elements in the periodic table that are always unstable. Highlight these on the diagram below.

1 H 1.008																	18 He 4.0026
3 Li 6.94	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305	3	4	5	6	7	8	9	10	11	12	13 Al 26.982	14 Si 28.085	15 P 30.974	16 S 32.06	17 Cl 35.45	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.630	33 As 74.922	34 Se 78.97	35 Br 79.904	36 Kr 83.798
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.95	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71 * #	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89-103 #	104 Rf (265)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (294)	118 Og (294)
* Lanthanide series			57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
# Actinide series			89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

## Question 7

Every unstable isotope undergoes radioactive decay at a particular rate. This rate is referred to as the **half-life** of an isotope. Half-lives may be very short, just a few seconds, or very long, up to many millions of years, depending on the isotope. Carbon-14 has a half-life of 5,730 years.

Examine the following diagram and, from it, explain the meaning of the term 'half-life'.



## Question 8: Suggested videos

Watch the following videos before your excursion to ANSTO to get the most out of your visit (<https://www.youtube.com/user/ANSTOVideos>):

[OPAL research reactor animation](#): This video is an overview of the structure and functions of the OPAL nuclear reactor.

[Echidna: High speed powder diffractometer](#): This video shows how neutrons from inside the OPAL reactor are used in neutron diffraction instruments to study material structure at the atomic level.

[Radiocarbon dating on ANSTO's VEGA accelerator](#): This video shows how VEGA particle accelerator is used to determine the age of artefacts and environmental samples up to 50,000 years old.

[Safely managing Australia's radioactive waste](#): Nuclear research and medicine produced by ANSTO has benefited generations of Australians since the 1960s. With benefits, come responsibilities, and the by-products of nuclear research and medicine includes radioactive waste. ANSTO responsibly manages this waste in both the long and short term.



### Question 9

At ANSTO, you will learn about the properties and uses of different natural and human-made radioisotopes. Refer to information about each isotope in our online radioisotope posters to complete the table below (<https://www.ansto.gov.au/education/resources/posters>).

Isotope name	Number of protons	Number of neutrons	$\begin{matrix} A \\ Z \end{matrix} X$	Half-life	Balanced nuclear decay equation (including the types of radiation produced when it decays)	Use
Molybdenum-99						
Technetium-99m						
Iodine-131						
Cobalt-60						
Carbon-14						
Uranium-235						
Beryllium-10						
Chlorine-36						

## During-excursion questions

### Question 1

A **cloud chamber** allows us to see the effect of different nuclear radiation. Radioactive particles move through the alcohol vapour in the cloud chamber and strip electrons from surrounding atoms. This leaves a white trail in the cloud chamber that you can see.

Read the information about the different types of nuclear radiation.

1. Look in the cloud chamber and observe the white vapour trails produced by different particles.
2. Draw the trails left by each particle and describe the trail and length of time it lasts.

#### Alpha


#### Beta


#### Proton


## Question 2

At ANSTO, we use different portable devices to monitor levels of radiation.

Next to the picture of each device below, write the name of the device and a sentence or two to explain how it works.

Device	Name of the device and how it works
	
	
	

### Question 3

Your education officer will demonstrate a radiation experiment using the scintillation counter and some radioactive sources.

What you will be investigating:

- How radioactive are different household objects? Which of these sources should we choose for the experiments below and why?

And one of the following:

- How does radioactivity change with distance from the source?
- How does the thickness of a shielding material affect radiation penetration?
- How do different types of shielding material affect radiation penetration?

*When you return to school you will need to write an aim, hypothesis, equipment and method for the experiment*



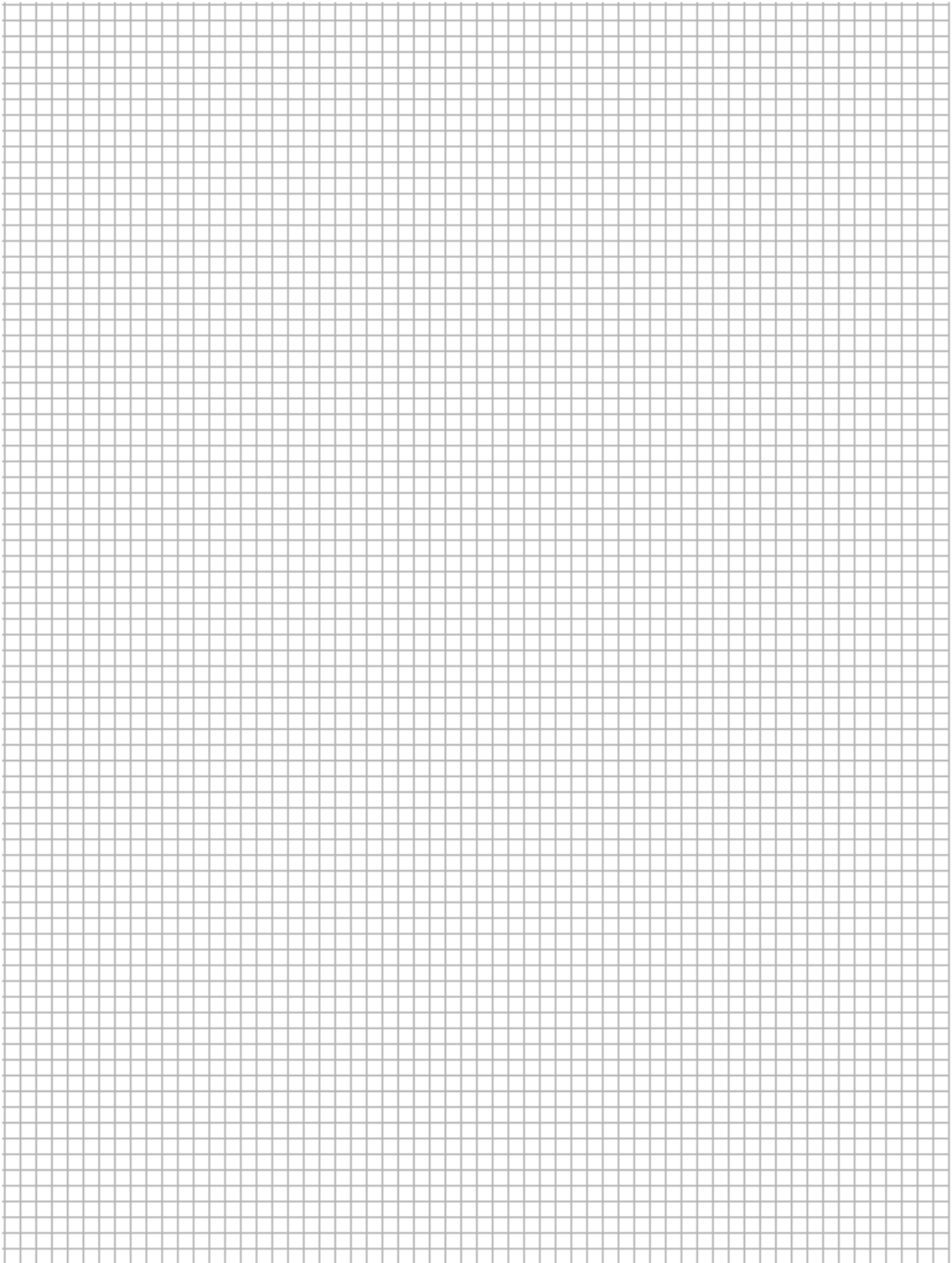
#### Risk assessment:

Name of risk	Ways of managing named risk


**Results:**

<b>Object</b>	<b>Radioactivity (counts per second, cps)</b>	<b>Extra notes</b>
<b>Potash</b>		
<b>Uranium glass</b>		
<b>Tungsten welding rods</b>		
<b>Gas mantle</b>		
<b>Radium watch</b>		
<b>Uranium mineral (autunite)</b>		
<b>Fiestaware plate</b>		

	<b>Radioactivity (counts per second, cps)</b>			
	<b>Trial 1</b>	<b>Trial 2</b>	<b>Trial 3</b>	<b>Mean</b>



## Notes

Use this space to take your own notes about areas of interest relevant to your own depth study