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Physics Module 8

From the Universe to the Atom WORKSHEETS

Worksheet 1 Origin of the Elements

Guided Notes. (Make your own summary)

Student Name.....................................

1.
The "Big-Bang" theory is accepted (for now) because it explains 3 critically important observations about the Universe. Outline what these are and how B-B explains them.

2.
a) At the instant of the B-B, the Universe was pure energy. How is it thought that matter was produced? Outline the "stages" from pure energy to complete atoms.

b) If the Universe has always been expanding rapidly, how come galaxies, stars etc. were able to form?

c) What is the evidence for your answer to (b)?

3.
a) Sketch the Hertzsprung Russell Diagram & show the "main sequence" of stars. Label the axes (numbers not required) Mark the position of the Sun.

b) Relate the "spectral class" colours to surface temperature of a star. What aspect(s) of Physics are involved?

c) What is meant by "absolute magnitude" of a star?

4.
a) Write a word equation for the overall fusion reaction in all main sequence stars.

b) There are 2 quite different fusion processes possible. Give an outline of each.

c) What determines which of these processes predominates in any given star?

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Worksheet 2 Life & Death of Stars

Fill in the blanks

Student Name.....................................

Stars are created in huge interstellar a)....................... which collapse due to b)........................ As they do so, the density and temperature c)..........................., until atoms are forced together and begin d)................................ in the core of the new star.

All new stars plot onto a H-R diagram on a line along the bottom of the e).. known as the "f)....................... curve". Generally, the more massive the star is, the higher is its g).................................... and .... The more massive a star, the faster it burns its fuel and the h).................................. its life-span.

In smaller main sequence stars the main fusion reaction is the i)...................................... chain. This fuses j)............................... to k)...................... In larger stars the same overall result is achieved via a more complex pathway involving l)......................, ... and....................... nuclei. This is called the "m)..................... cycle". Eventually, the core of the star becomes depleted in n)......................, so fusion slows and the core o)................................. under gravity. This heats the core enough for fusion of p)....................... into .... to begin.

The outer layers of the star expand outwards so the star becomes q)......................... luminous, but its surface temperature r).......................... It is now a s)........... .... star. In and around the core many other fusion reactions occur which produce many other t)................................ This is called "u)...

Eventually, the star runs out of fuel and begins to die. If it is small, there may be minor "flashes" of energy which blow away the outer layers as a "v)..". Meanwhile the core collapses to form "w).............................. matter", radiating residual heat with x)....................... luminosity, but y)......................... temperature. This remnant is known as a z).................................... star.

If the star is larger than about 5 times aa)................................, when the fuel runs out the core collapses very suddenly. The infalling outer layers explode as a ab)..., which briefly shines as bright as a million suns. This blows away all the outer layers, and compresses the collapsing core even further. Depending on the size of the core, it may collapse to form either a ac)................................. or a ....

Worksheet 3 Test-Style Questions

Student Name..............................

1.
a) Sketch a H-R diagram (label axes, but no values required) and show the positions of:
i) the ZAMS curve
ii) main sequence
iii) red giants
iv) white dwarfs

b) On your diagram, add an "X" to mark the approx. position of the Sun, and show with a dotted line its future expected evolution.

2.
a) Compare and contrast the proton-proton chain with the CNO cycle. (Specific nuclear equations are not required, but more general word equations are.)

b) Relate the mass of a main sequence star to the predominant reaction occurring.

3.
a) What does "nucleosynthesis" refer to?

b) When & where does most nucleosynthesis occur? (related to life stages of stars)

c) What is the significance of the element iron in the overall nucleosynthesis process?

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Worksheet 4 History of Atomic Structure

Guided Notes.

(Make your own summary)

Student Name.....................................

1.
What was the prevailing model of an atom through most of the 19th century?

2.
a) Describe the the experiment used by JJ Thomson in 1897 to discover the electron.

b) What was he able to calculate from the experiment?

c) Describe the new model of the atom Thomson proposed.

3.
a) Describe the the famous "oil drop" experiment done by Robert Milliken in 1909.

b) What was he able to calculate from the results?

4.
a) Based on Thomson's "plum pudding" model, Rutherford had calculated the likely effect of beaming alpha particles through a target of heavy metal atoms. What was the prediction?

b) Who carried out the experiment to test this prediction?

c) What was the unexpected result?

5.
Sketch Rutherford's new atomic model and add notes which account for the results of the alpha scattering experiment.

6.
a) Outline Rutherford's experiment of 1917, its results, and his argument for the existence of protons.

b) After the acceptance of the existence of protons, what was the remaining problem about the atomic nucleus?

7.
a) Describe Chadwick's experiment with a labelled sketch.

b) Outline how he was able to determine the properties of the neutron by measuring the energy of dislodged protons.

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Worksheet 5 Oil-Drop Experiment
Skills Exercise

Student Name.....................................

To simulate one aspect of Millikan's "oil-drop" experiment, some small (identical) marbles were added to a series of 8 identical containers. These were sealed so that the contents cannot be seen. The number of marbles added to each container was random.

Each container was then weighed.
The masses (in grams) were:
20.5, 8.5, 16.0, 7.0, 43.0, 28.0, 11.5, 10.0

1. Transfer these data to the table, re-arranging in order of increasing mass. Complete the table with the mass difference of each container compared to the previous one.

increasing mass ⟶

Mass of container + marbles								
Diff. from previous	/							

2.
From this data, deduce the possible mass of each marble. Explain your reasoning.

3. Explain how this exercise relates to the oil-drop experiment.

4.
What is an alternative answer for the mass of each marble and how could this be the case?

5.
How can the experiment be modified to reduce the chance of this "error"?

Worksheet 6 Rutherford-Bohr Model of the Atom

Fill in the blanks

Student Name.....................................

Rutherford's model of the atom:
• in the centre is a tiny, dense a).............................
• Electrons (discovered by b)................................)
are in c)................................ around the outside.
The model had a major problem: theoretically, electrons which are d)................................ should constantly emit e)...................................., causing all matter to constantly f)....................... with light.

The "g)..." of an element refers to the precise set of h).................................... of light emitted if the element is energised, for example, in a high-voltage i).......................... tube. The lines are visible if the light is viewed through a j)...

The visible lines in the spectrum of k)........................ had been named the "l)................................ Series", and the m)....................................... equation had been formulated to calculate the n)............................. of each of the lines in the series.

Bohr used the evidence of the Balmer Series to refine Rutherford's atomic model. He suggested:

• Electrons orbit in "o)..............................", in which they will not p)..
• Electrons can q)............................. from one orbit to another. When they do so they must r)........................... or .... an amount of energy. This energy difference relates to the s)................................ of a spectral line in accord with t)...........................'s Quantum Theory and the u)................................. equation.
• Electrons in "v).............................. orbits" have a quantity of w)...................................... which is always a multiple of $h/2\pi$.

Bohr was able to link his idea to the Balmer Series of hydrogen spectral lines. In fact, it is highly unlikely he could have developed his idea without this evidence.

However, the Bohr model had a number of limitations:
• It worked only for x)...
• It could not explain the different y)..................................... of the spectral lines.
• There was evidence from the "z)......................... Effect", and the observed "aa)............................." spectral lines, that each orbit was actually ab)........................ ....

The model could not explain these observations.

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Worksheet 7 The Bohr Model
Practice Questions

Student Name......................................

1.
Outline the major problem with Rutherford's atomic model, based on the accepted theory of that time.

2.
a) What is the "Balmer Series"?

b) Calculate the wavelength of the H_β spectral line for hydrogen, given that $n_i = 4$ and $n_f = 2$.

c) Use the wave equation, and Plank's equation to find the amount of energy carried by one photon of the H_β line.

d) According to Bohr, what does this amount of energy represent within a hydrogen atom?

3.
The H_χ spectral line for hydrogen is due to an electron dropping from the 5th to the 2nd orbit. Compared to the H_β line (in Q3):

a) Would a photon of the H_χ line carry more, less, or the same amount of energy? Explain.

b) Would the H_χ line have a higher, lower, or the same frequency? Explain.

c) Would the H_χ line have a longer, shorter, or the same wavelength? Explain.

4.
a) List, in brief form, 3 of "Bohr's Postulates".

b) List, in brief form, 4 limitations of the Bohr model.

5.
It is known that other spectral lines for hydrogen are present in the infra-red and ultra-violet parts of the spectrum. One line, for example, is due to electrons dropping from the 8th to the 1st orbit.

a) Use the Rhydberg equation to calculate the wavelength of this spectral line and state if it is likely to be infra-red or ultra violet.

b) Without any calculation, suggest which orbits might be involved to produce the <u>lowest possible</u> frequency of a hydrogen spectral line. Explain your reasoning.

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Worksheet 8 Matter Waves
Practice Questions

Student Name....................................

1.
Use de Broglie's equation to calculate:
a) the wavelength of an electron with velocity 2.25×10^6 ms^{-1} (mass of electron = 9.11×10^{-31}kg)

b) the velocity of an electron if its quantum wavelength is 4.75×10^{-9}m.

c) Use the wave equation to find the quantum frequency of the electron in (b).

d) Use Plank's equation to calculate the quantum energy of the electron in (b).

2.
Describe the impact of de Broglie's proposal that particles could have wave properties.
Account for this reaction by the scientific community.

3.
Outline the experiment of Davisson & Germer.
State the result of the experiment and explain the significance of this result.

4.
Explain how de Broglie would describe Bohr's "allowed orbits" around the nucleus.

Worksheet 9 De Broglie & Matter Waves

Fill in the blanks

Student Name....................................

Louis de Broglie argued that if Einstein's photons of light are waves with a)....................... properties, then electrons could be b)............................. with c)...................... properties.

He extended Bohr's model to derive an equation for the d)............................. (wave measurement) of the electron. Bohr's "allowed orbits" were explained as e)..................................... waves, with an integer number of f)................................. fitting exactly around that orbit.

De Broglie's hypothesis had g)............................. impact on the scientific community. It seemed an interesting idea, but there was no h).......................... from observations or i)... to connect it to.

Two scientists, j).......................... & .... carried out an experiment in which a beam of k).............................. was aimed at a crystal. They detected an l)............................. pattern which proved that the electrons were undergoing m)................................

This proved that electrons do have n).................... properties, and confirmed de Broglie's hypothesis.

o)............................ is a wave phenomenon in which waves which penetrate a small aperture, then act like a point source of waves and p)....................... in a q)... pattern. When waves from 2 (or more) apertures overlap, they r).................................. with each other. Where crest meets crest the waves s)................. .... creating a higher t).................................. wave. Where crest meets trough, the waves u)............................ each other. With light, this results in a pattern of v)........................... and .... spots.

Following the confirmation of de Broglie's theory, the science of Quantum Mechanics was given a complete theoretical framework by the work of Werner w)......................................, Wolfgang x)............................. and (especially) y)................... ...., who is considered the "father of Quantum Mechanics"

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Worksheet 10 Atoms, Elements & Isotopes

Student Name.....................................

Guided Notes. (Make your own summary)

1. All atoms are composed of 3 types of particles:

.........................., ... & ....

2. The number present of 2 of these are always equal. Which two?
.... = ...

3. Define “Atomic Number”.

4. How can you calculate the “Mass Number” for any atom?

5. Mass No. is also known as...?

6. Why are the electrons NOT counted?

7. Why is it that Mass Numbers are always integer numbers, but the RAM (At.Weight) on the Periodic Table is nearly always NOT an integer.

8. How do the isotopes of an element compare to each other...

a) in their chemistry?

b) in atomic structure?

9. What is a “radioisotope”?

10. List 3 types of nuclear radiation, with detail of what each type actually is.

11. If an isotope undergoes alpha decay:
a) what is basically “wrong” with the atom?

b) What happens to the Mass No. of the atom?

c) What happens to the Atomic No.?

12. If an isotope undergoes beta decay:
a) what is basically “wrong” with the atom?

b) What happens to the Mass No. of the atom?

c) What happens to the Atomic No.?

13. Sketch a graph to show the (approx) position of the “Line of Stability” (LoS) for the elements. Label the axes. Values are not required.

14. On the sketch graph add shadings & labels to indicate where isotopes would be found which are:

- **stable**
- **probable alpha decay isotopes**
- **probable beta decay isotopes**

15. How can radiations cause ionisation?

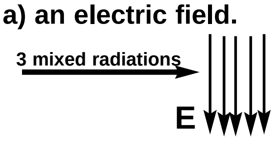
16. a) Which radiation type has the highest ionising ability?

b) Which one has least?

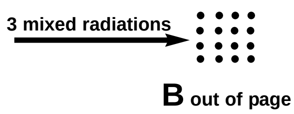
17. a) Which radiation type has the highest penetrating ability?

b) Which one has least?

18. Complete these sketches to describe the behaviour of the 3 radiations as they pass through:
a) an electric field.



b) a magnetic field.



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Worksheet 11 Radioactive Decay Equations Practice Exercise

Student Name......................................

Alpha Decay Equations

Work out the missing nuclide, identifying
- Mass Number & Atomic Number
- Symbol & name

a) $^{222}_{86}\text{Rn} \longrightarrow \square + ^{4}_{2}\text{He}$

b) $^{241}_{95}\text{Am} \longrightarrow \square + ^{4}_{2}\text{He}$

c) $^{210}_{84}\text{Po} \longrightarrow \square + ^{4}_{2}\text{He}$

d) $\square \longrightarrow ^{233}_{91}\text{Pa} + ^{4}_{2}\text{He}$

e) $\square \longrightarrow ^{210}_{84}\text{Po} + ^{4}_{2}\text{He}$

f) Write the equation for the alpha decay of actinium-227

g) Write the equation for the alpha decay of plutonium-244

h) Write the equation for the alpha decay of radon-224. This decay also releases gamma radiation.

i) Write the equation for the alpha decay of Bi-209.

j) Write the equation for the alpha decay of thorium-232

Beta Decay Equations

If each of the following nuclides underwent beta decay, write the symbol, Mass Number & Atomic Number of the new nuclide.

a) hydrogen-3

b) thorium-234

c) caesium-137

d) chlorine-38

e) uranium-239

Write complete decay equations for the beta decay of:

f) lithium-8

g) xenon-135

h) phosphorus-35

i) sodium-24 (also gamma released)

j) beryllium-10

k) cobalt-60 (also gamma released)

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Worksheet 12 Practice Problems
Rate of Decay

Student Name.....................................

1.
The radiation from a sample of a radioisotope was measured to be 200 units. The same sample, measured 20 years later, was emitting just 12.5 units of radiation.
a) What is the half-life of this isotope?

b) What was the radiation level 10 years after the start?

c) What radiation level would you expect after a further 10 years? (i.e. total 30 years from the start)

2.
A bone found in an ancient tomb was analysed using carbon-14 analysis. (C-14 half-life = 5,730 yrs) When alive, bone is expected to have 420 ppm (parts per million) of C-14. The bone was found to have 105ppm of C-14.
How old is the bone? Explain your reasoning.

3.
Potassium-40 (K-40) is a radioisotope which decays (half-life of 1.3 billion years) to form the gas argon. Potassium is common in certain minerals. In some types of crystals, any argon formed is trapped, and can be collected and measured, to find the original starting quantity of potassium-40.

Analysis of a crystalline rock reveals 28 mg/kg of argon trapped within it. Analysis of radiation shows that there is 4 mg/kg of K-40 in the rock. How old is it? Explain your reasoning.

4.
Iodine-131 undergoes beta decay (plus gamma) with a half-life of 8.0 days.
a) Write the decay equation.

b) Calculate the decay constant.

c) What % of I-131 remains in a sample after exactly 5 days?

5.
Am-241 is an alpha-decayer with half-life of 433 yrs.
a) Calculate the decay constant.

b) What % of a sample remains after 15 years?

6.
Phosphorus-35 emmits emits beta rays and has a half-life of just 47.3 minutes.
a) Calculate the decay constant.

b) What % of a sample remains after 5 hours?

Challenge Problems

7. After 1 year, 16% of a sample of polonium-210 remains. What is its half-life, in days?

8.
Hydrogen-3 (also called "tritium") has a half-life of 12.3 years. How many years have elapsed when only 0.38% of a sample remains?

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Worksheet 13 Mass Defect Practice Problems

Student Name......................................

Use the data table at right.

For each of the following nuclear reactions calculate:
a) the Mass Defect (u)
b) the energy released (MeV)

Data for Calculations

Nuclide	Nuclear Mass (u)	Nuclide	Nuclear Mass (u)
$^{1}_{0}n$	1.0087	$^{1}_{1}H$	1.0073
$^{4}_{2}He$	4.0026	$^{7}_{3}Li$	7.0160
$^{9}_{4}Be$	9.0122	$^{12}_{6}C$	11.9967
$^{22}_{11}Na$	21.9780	$^{25}_{12}Mg$	24.9575
$^{92}_{36}Kr$	91.8804	$^{92}_{38}Sr$	91.8776
$^{141}_{56}Ba$	140.8167	$^{145}_{56}Ba$	144.8115
$^{235}_{92}U$	235.0439	$^{239}_{94}Pu$	239.0446

1. $^{9}_{4}Be + ^{4}_{2}He \longrightarrow ^{12}_{6}C + ^{1}_{0}n$

2. $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$

3. $^{7}_{3}Li + ^{1}_{1}H \longrightarrow ^{4}_{2}He + ^{4}_{2}He$

4. $^{239}_{94}Pu + ^{1}_{0}n \longrightarrow ^{145}_{56}Ba + ^{92}_{38}Sr + 3\,^{1}_{0}n$

5. $^{22}_{11}Na + ^{4}_{2}He \longrightarrow ^{25}_{12}Mg + ^{1}_{1}H$

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Worksheet 14 The Standard Model of Matter Guided Notes.

(Make your own summary)

Student Name.....................................

1.
List the four fundamental forces in order of increasing strength.
For each, add notes to cover:
a) which property of matter the force acts upon.
b) which phenomenon(a) are controlled by this force.
c) Which of the "gauge bosons" carries this force between interacting particles.

2.
a) Discuss the concept of "unification of fundamental forces" with regard to the early Big-Bang.

b) Which forces have already been proven to be "unified"?

c) What is meant by the "GUT" and the "ToE"?

3.
a) Explain how protons and neutrons end up with their electric charge values, in terms of their quark composition.

b) What binds the quarks together within a proton, neutron or meson?

c) What binds the nucleons together within the nucleus?

d) What property of mesons contributed to the early confusion about cosmic rays & the "particle zoo"?

4.
a) What are "leptons"?

b) Which of the fundamental forces do leptons "feel"? (and why?)

5.
a) Describe, with examples, what "anti-particles" are.

b) What is the result of a particle & its anti-particle interacting with each other?

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Answer Section

Worksheet 1

1.

• the expansion of the Universe, as predicted by Friedmann (from Einstein's Gen.Rel.) and observed in the "red-shift" of distant galaxies first measured by Hubble.
• the Cosmic Background Radiation. This is microwave radiation coming from all directions, thought to be the "afterglow" of B-B.
• the composition of the Universe (mostly H & He) which can be predicted mathematically from theoretical considerations of conditions soon after B-B.

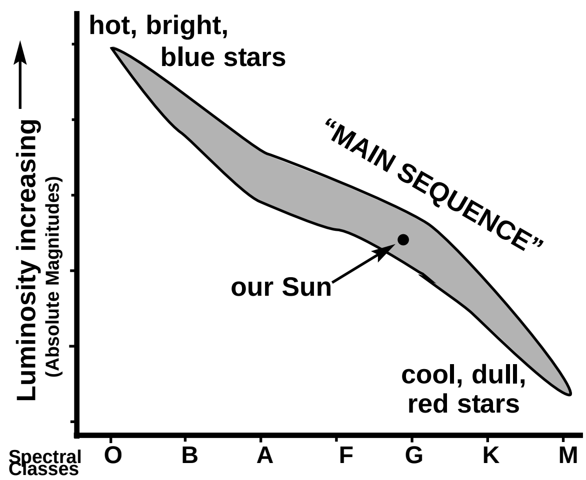
2.

a) At the B-B, everything was energy. Within the first seconds & minutes, particles (protons, electrons, etc) began "condensing" from the energy according to $E=mc^2$. As expansion & cooling continued, some protons & neutrons formed atomic nuclei, such as He. Very few larger nuclei could form. After about 400,000 years it became cool enough for atoms of H & He to form as the nuclei acquired orbital electrons.

b) There were localised concentrations of matter where gravity could attract a "lump", so it collapsed to form (eventually) a galaxy. Within it were many smaller concentrations in which gravity could cause collapse to form stars, and (later) planets.

c) The CBR shows a pattern of fluctuations which is totally consistent with this idea.

3. (a)



b) Spectral classes relate to temperature according to Wien's Law and the "black-body" radiation curves. Basically, the hotter the star, the shorter the wavelength (higher frequency) of the "peak" light emissions.

3. (c)
Absolute magnitude is the "luminosity" (brightness, or amount of energy per m^2, per second) when viewed from a <u>standard distance</u> from the star.

4.
a) Hydrogen ⟶ Helium + energy

b) In the proton-proton chain, hydrogen nuclei (protons) fuse together. Then a chain of radioactive decays & further fusions follow, until stable He-4 nuclei are formed.

In the "CNO cycle", carbon nuclei act as catalysts in a cycle of fusions & radioactive decays which keep fusing protons to form nitrogen & oxygen nuclei. Finally, a fusion splits to form He-4 and re-generate the carbon catalyst.

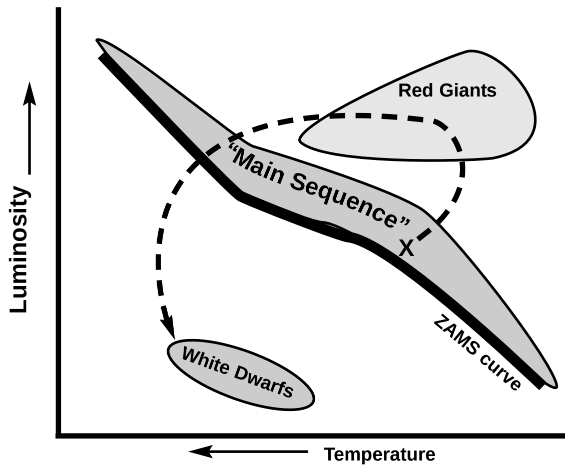
c) P-P chain predominates in small stars; CNO cycle in large stars. Medium-size stars carry out both processes, with CNO more predominant in larger mass stars

Worksheet 2

a) gas clouds	b) gravity
c) increase	d) nuclear fusion
e) main sequence	f) ZAMS
g) temperature & luminosity	
h) shorter	i) proton-proton
j) hydrogen	k) helium
l) carbon, nitrogen & oxygen	
m) CNO	n) hydrogen
o) collapses	p) helium into carbon
q) more	r) decreases
s) red giant	t) elements
u) nucleosynthesis	v) planetary nebula
w) degenerate	x) low
y) moderate/high	z) white dwarf
aa) solar mass	ab) supernova
ac) neutron star or a black hole	

Worksheet 3

1.



Answer Section

Worksheet 3 (cont.)

2.

a) P-P & CNO processes are similar in that both involve fusion of hydrogen (protons) into helium nuclei. Both involve several fusion steps, with radioactive decay(s) in between some steps.

The processes are very different in detail.
P-P involves only the isotopes of hydrogen & helium.
CNO involves carbon, nitrogen & oxygen nuclei, plus protons, with carbon acting as a catalyst.

b) Small stars carrying out only P-P fusion. In larger stars, the higher pressure & temperature favours the occurrence of CNO reactions until it predominates in the larger main sequence stars.

3.

a) Nucleosynthesis is the process of making larger atomic nuclei by fusion in the giant stars. This can typically produce all the nuclei of the Periodic Table up to about lead, although relatively few nuclei larger than iron are produced.

b) In the "red giant" stars, which have left the main sequence after their cores became depleted in hydrogen.

c) Nuclei as large as iron can be formed by fusion with the net release of energy. To make nuclei larger than iron involves fusions which absorb energy. This tends to cause a build-up of iron & nickel in an older star.
(and explains why Earth has a lot of iron & nickel, since our solar system formed from the remnants of an exploded star)

Worksheet 4

1.

Atoms were believed to be unbreakable and NOT composed of any smaller parts.

2.

a) Thomson fired cathode rays (electrons) through an electric field and a magnetic field. The fields were arranged to produce opposite deflections. By adjusting the fields, he could exactly cancel out the deflections, so electric force = magnetic force.

b) Field strengths could be calculated from voltage & current settings. Using these, he was able to determine the <u>charge/mass ratio</u> of the cathode rays. This proved they were particles... electrons.

c) His "plum pudding" model proposed a positively charged matrix, with electrons embedded in it.

3.

a) Tiny droplets of oil were sprayed into a chamber where some fell under gravity past a microscope. (Used to observe them.) When sprayed, some droplets developed a small static charge. They fell between charged plates, so by adjusting the voltage, the motion of a droplet could be balanced against gravity.
At that point gravity force = electrical force.

b) This allowed the charge on a droplet to be measured. From hundreds of charges, Milliken found they were all multiples of a certain value. He argued that this was the charge on a single electron.

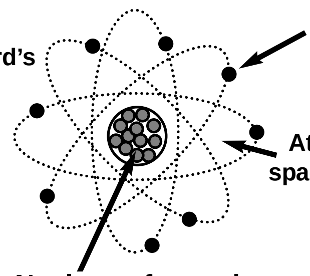
4.

a) That the alpha particles would mostly pass through, with a few small angle deflections.

b) Geiger & his student Marsden.

c) A few alpha's were deflected by large angles or even bounced back.

5.



6.

a) He "fired" alpha radiation into nitrogen gas and recognised the "signature" of hydrogen atoms in his detectors. He proposed that the "hydrogen" (a proton) must have been inside the nucleus of the nitrogen atoms and had been knocked out by the energy of the alpha collision.

$$^{14}_{7}N + ^{4}_{2}He \longrightarrow ^{17}_{8}O + ^{1}_{1}H$$

Nitrogen nucleus, Alpha particle, Oxygen nucleus, Hydrogen nucleus

b) The number of protons in an atom (to balance the electron charge) was NOT enough (often less than half) to account for the atomic mass.

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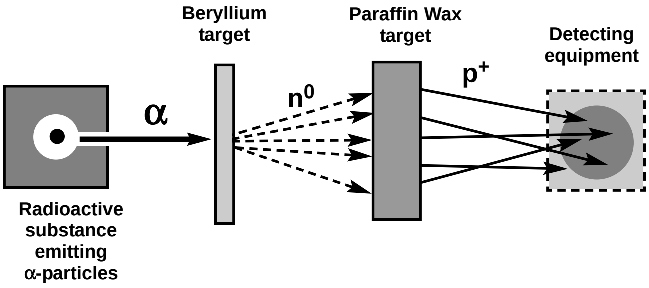
Answer Section

Worksheet 4 (cont.)

7. (a)



b) By measuring the momentum and KE of the protons which hit the detectors, he could use the conservations laws (for momentum & energy) to find the <u>mass</u> of the undetectable neutrons.

Since electric fields had no effect on them, it was known they had no charge.

The mass value & zero charge was just right to explain the "missing" mass of atoms.

Worksheet 5

1.

Mass of container + marbles	7.0	8.5	10.0	11.5	16.0	20.5	28.0	43.0
Diff. from previous	/	1.5	1.5	1.5	4.5	4.5	7.5	15

2.
The smallest difference is 1.5g and all differences are multiples of 1.5.
Therefore, it is likely that this is the mass of each marble.

3.
Milliken used the same logic to deduce the charge of one electron because his oil drops had charges which were all multiples of the same small charge.

4.
It is possible that the marbles are half of 1.5g each and all those with differences of 1.5 have 2 extra marbles, not one. (or other fractions 1/3, 1/4 etc.)

5.
Increase the number of random containers studied. It becomes very unlikely that a large number of random sets of marbles can all be multiples of an even numbers of marbles, with none having an odd number.
(Milliken measured the charge of hundreds of oil-drops)

Worksheet 6

a) nucleus **b) J.J.Thomson**
c) orbit
d) accelerating/in circular motion
e) (electromag) radiation **f) glow**
g) emission spectrum **h) wavelengths**
i) discharge tube **j) spectroscope**
k) hydrogen **l) Balmer**
m) Rhydberg **n) wavelength**
o) "allowed" orbits
p) radiate energy/emit light
q) jump **r) absorb or emit**
s) wavelength/frequency **t) Plank's**
u) Rhydberg **v) allowed**
w) angular momentum **x) hydrogen**
y) intensities/brightness **z) Zeeman**
aa) hyperfine **ab) divided into sub-orbits**

Worksheet 7

1.
The existing theory for EMR stated that electrons accelerating in circular motion should constantly emit light energy, but obviously they don't.

2.
a) Balmer Series is the 4 lines of visible light in the emission spectrum for hydrogen.

b) $\frac{1}{\lambda} = R_H(1/n_f^2 - 1/n_i^2)$

$= 1.097\text{x}10^7(1/2^2 - 1/4^2)$

$1/\lambda = 2.057 \times 10^6$

$\therefore \lambda = 4.86\text{x}10^{-7}$ m

c) $c = \lambda.f, \quad \therefore f = c/\lambda$

$= 3.00\text{x}10^8 / 4.86 \text{x}10^{-7}$

$= 6.17\text{x}10^{14}$Hz.

$E = h.f$

$= 6.63\text{x}10^{-34} \times 6.17\text{x}10^{14}$

$= 4.09\text{x}10^{-19}$ J.

d) The energy difference between the 2nd and 4th quantum levels (or "allowed orbits").

3.
a) More energy, because it is the difference between 5th-2nd orbits, compared to 4th-2nd.

b) Higher frequency, because Plank's E = hf shows a direct relationship between energy and frequency.

c)Shorter, because frequency and wavelength are inversely related by the wave equation , v=lf.

4.a)
- **electrons revolve only in certain stable, "allowed orbits"**
- **Energy must be absorbed, or emitted, in quantised amounts when an electron jumps from one orbit to another.**
- **Within the "allowed orbits" the electron's angular momentum is quantised to a multiple of h/2π.**

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Answer Section

Worksheet 7 (cont.)

4. b)
*** it applied only to the hydrogen atom.**
*** it could not explain the different intensities of the spectral lines.**
*** it could not explain the "hyperfine" spectral lines.**
*** it could not explain the "Zeeman Effect".**

5.

a) $\frac{1}{\lambda} = R_H(1/n_f^2 - 1/n_i^2)$

$= 1.097\times10^7(1/1^2 - 1/8^2)$

$1/\lambda = 1.03 \times 10^7$

$\therefore \lambda = 9.72\times10^{-8}$ m

It must be UV because it is a shorter wavelength than the visible Balmer series line.

b) The lowest frequencies will come from the smallest energy "jumps". These would be between adjoining orbits such as 6-5 or 8-7.

Worksheet 8

1.

a) $\lambda = \frac{h}{mv} = 6.63\times10^{-34}/(9.11\times10^{-31} \times 2.25\times10^6)$

$= 3.23\times10^{-10}$ m

b) $\lambda = \frac{h}{mv}$ so $v = h/m\lambda$

$= 6.63\times10^{-34}/9.11\times10^{-31}\times4.75\times10^{-9}$

$= 1.53\times10^5\ ms^{-1}$.

c) $c = \lambda f$, so $f = c/\lambda = 3.00\times10^8/4.75\times10^{-9}$

$= 6.32\times10^{16}$ Hz

d) $E = h.f$

$= 6.63\times10^{-34} \times 6.32\times10^{16}$

$= 4.19\times10^{-17}$ J.

2. His proposal had very little impact at first. It was a "neat" idea, and mathematically valid, but the scientific community took little notice because there was no evidence from observation or experiment to link it to. It was not until the hypothesis was tested by Davisson and Germer that the Physics world really took notice.

3. Outline: In a vacuum tube, a beam of cathode rays (electrons) were beamed at a specially prepared nickel crystal.
Result: They detected an interference pattern in that part of the beam that reflected from the crystal.
Significance: this proved that electrons showed wave properties (diffraction & interference) and confirmed de Broglie's hypothesis.

4.
The "allowed orbits" are where the electron can exist as a standing wave around the nucleus. The orbit circumference is exactly equal to an integral number of electron wavelengths.

Worksheet 9

a) particle	b) particles
c) wave	d) wavelength
e) standing	f) wavelengths
g) very little	h) evidence
i) experiment	j) Davisson & Germer
k) electrons	l) interference
m) diffraction	n) wave
o) Diffraction	p) spread out
q) semi-circular	r) interfere
s) add together	t) amplitude
u) cancel	v) bright and dark
w) Heisenberg	x) Pauli
y) Erwin Schrodinger	

Worksheet 10

1. protons, electrons & neutrons

2. Protons = Electrons

3. Atomic No. is the number of protons (=electrons) in any atom of that element.

4. Add protons + neutrons.

5. Nucleon Number
(nucleon is the general name for any particle in the nucleus. ie, proton or neutron.)

6. The mass of electrons is so small (compared to a nucleon) that it is insignificant.

7. A Mass No. must be an integer because there must be a whole number of nucleons... no fractions of a particle.

RAM is the "weighted average" of the mix of different isotopes of that element, each with a different Mass No.

8.
a) same
b) different number of neutrons (only)

9.
An isotope which is unstable and emits radiation as it decays into a more stable form.

10.
alpha = helium nucleus = 2 protons + 2 neutrons
beta = a high-speed electron
gamma = high frequency wave, similar to x-rays

11.
a) The nucleus is too large for the "strong nuclear force" (very short-range) to hold it all together.

b) decreases by 4

c) decreases by 2

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Answer Section

Worksheet 10 (cont.)

12.

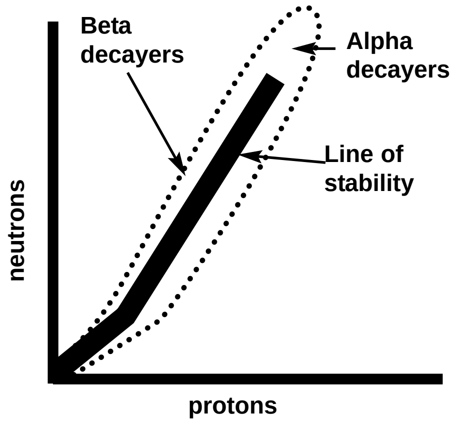
a) The ratio between protons:neutrons is beyond the "balance" necessary for stability.

b) no change

c) goes UP by one.

13. graph

14.
on graph

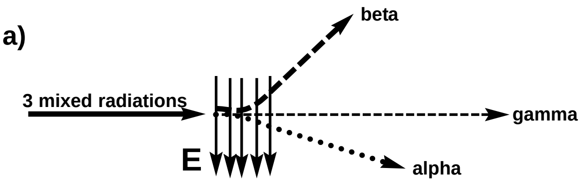


15.
Radiation may strike an electron & give it so much energy that it is knocked out of orbit. This turns that atom into an electrically charged ion.

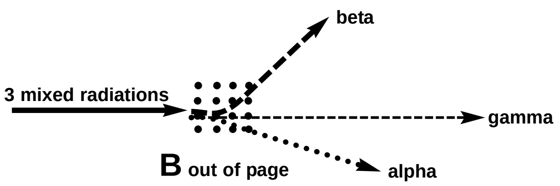
16.
a) highest = alpha
b) lowest = gamma

17.
a) highest = gamma
b) lowest = alpha

18. a)



b)



Worksheet 11

Alpha Decay

a) $^{218}_{84}Po$ Polonium

b) $^{237}_{93}Np$ Neptunium

c) $^{206}_{82}Pb$ Lead

d) $^{237}_{93}Np$ Neptunium

e) $^{214}_{86}Rn$ Radon

f) $^{227}_{89}Ac \longrightarrow {}^{223}_{87}Fr + {}^{4}_{2}He$ (Francium)

g) $^{244}_{94}Pu \longrightarrow {}^{240}_{92}U + {}^{4}_{2}He$ (Uranium)

h) $^{224}_{86}Rn \longrightarrow {}^{220}_{84}Po + {}^{4}_{2}He + \gamma$ (Polonium)

i) $^{209}_{83}Bi \longrightarrow {}^{205}_{81}Tl + {}^{4}_{2}He$ (Thallium)

j) $^{232}_{90}Th \longrightarrow {}^{228}_{88}Ra + {}^{4}_{2}He$ (Radium)

Beta Decay

a) $^{3}_{2}He$ Helium

b) $^{234}_{91}Pa$ Protactinium

c) $^{137}_{56}Ba$ Barium

d) $^{38}_{18}Ar$ Argon

e) $^{239}_{93}Np$ Neptunium

f) $^{8}_{3}Li \longrightarrow {}^{8}_{4}Be + {}^{0}_{-1}e^{-} + \bar{\nu}$

Lithium-8 — Beryllium-8 — β — anti-neutrino

g) $^{135}_{54}Xe \longrightarrow {}^{135}_{55}Cs + {}^{0}_{-1}e^{-} + \bar{\nu}$

h) $^{35}_{15}P \longrightarrow {}^{35}_{16}S + {}^{0}_{-1}e^{-} + \bar{\nu}$

i) $^{24}_{11}Na \longrightarrow {}^{24}_{12}Mg + {}^{0}_{-1}e^{-} + \bar{\nu} + \gamma$

gamma

j) $^{10}_{4}Be \longrightarrow {}^{10}_{5}B + {}^{0}_{-1}e^{-} + \bar{\nu}$

k) $^{60}_{27}Co \longrightarrow {}^{60}_{28}Ni + {}^{0}_{-1}e^{-} + \bar{\nu} + \gamma$

gamma

Answer Section

Worksheet 12

1.

a) 200 -->100 -->50 --> 25 --> 12.5
Four half-lives have gone by in 20 years, so half-life = 5 years.
b) 10 yrs = 2 half-lives, so radiation = 50 units.
c) Another 2 half-lives:
12.5 --> 6.25 --> 3.125 units.

2.

420 --> 210 --> 105
Two half lives have elapsed, so age = 11,500 yrs (approx)

3.

Original amount of K-40 = 28 + 4 = 32 mg/kg.
(amount of K-40 remaining plus amount of decay product formed)
32 --> 16 --> 8 --> 4
Three half-lives have elapsed, so age = 3.9 bill.yrs

4.

a)

$$^{131}_{53}\mathrm{I} \longrightarrow {}^{131}_{28}\mathrm{Xe} + {}^{0}_{-1}e^{-} + \bar{\nu} + \gamma$$

b) $\lambda = \ln(2) / t_{1/2} = \ln(2) / 8 = 0.693 / 8 = 0.0866\ d^{-1}$.

c) $N_t = N_0.e^{-\lambda t} = 100 \times e^{-0.0866x5}$
$= 100 \times 0.649 = 64.9\ \%$

5.

a) $\lambda = \ln(2) / t_{1/2} = \ln(2) / 433 = 0.693 /433 = 0.00160\ (year^{-1})$

b) $N_t = N_0.e^{-\lambda t} = 100 \times e^{-0.0016x15}$
$= 100 \times 0..976 = 97.6\ \%$

6.

a) $\lambda = \ln(2) / t_{1/2} = \ln(2)/47.3 = 0.693/47.3 = 0.0147\ (min^{-1})$

b) 5 hrs = 300 min.
$N_t = N_0.e^{-\lambda t} = 100 \times e^{-0.0147 \times 300}$
$= 100 \times 0.0122 = 1.22\ \%$

7.

$N_t = N_0.e^{-\lambda t}$ So, $16 = 100.e^{-\lambda t}$
$0.16 = e^{-\lambda t}$
$\therefore \ln(0.16) = -\lambda t$
now t = 365, so $\lambda = -\ln(0.16) / 365 = 0.00502\ d^{-1}$

$\lambda = \ln(2) / t_{1/2}$ so $t_{1/2} = \ln(2) / \lambda$
$= 0.693 / 0.00502$
$= 138$ days

8.

$\lambda = \ln(2) / t_{1/2} = \ln(2) / 12.3 = 0.0563\ yr^{-1}$

$N_t = N_0.e^{-\lambda t}$ So, $0.38 = 100.e^{-0.0563 \times t}$
$0.0038 = e^{-0.0563 \times t}$
$\therefore \ln(0.0038) = -0.0563 \times t$
$t = \ln(0.0038) / -0.0563 = 99$ years

Worksheet 13

1. a)
Mass defect = (mass reactants) - (mass products)
= (9.0122+4.0026)-(11.9967+1.0087)
= 13.0148-13.0054
= 0.0094 u
b) Energy release = 0.0094 x 931.5 = 8.756 MeV

2. a)
Mass defect = (mass reactants) - (mass products)
= (235.0439+1.0087)-(140.8167+91.8804+3.0261)
= 236.0526 - 235.7232
= 0.3294 u
b) Energy release = 0.3294 x 931.5 = 306.8 MeV

3. a)
Mass defect = (mass reactants) - (mass products)
= (7.0160+1.0073)-(4.0026 x 2)
= 8.0233 - 8.0052
= 0.0181 u
b) Energy release = 0.0181 x 931.5 = 16.86 MeV

4. a)
Mass defect = (mass reactants) - (mass products)
= (239.0446+1.0087) - (144.8115+91.8804+3.0261)
= 240.0533 - 239.7180
= 0.3353 u
b) Energy release = 0.3353 x 931.5 = 312.3 MeV

5. a)
Mass defect = (mass reactants) - (mass products)
= (21.9780+4.0026) - (24.9575+1.0073)
= 25.9806 - 25.9648 = 0.0158 u
b) Energy release = 0.0158 x 931.5 = 14.72 MeV

Worksheet 14

1.

Gravity
a) Acts on mass.
b) Holds galaxies together, forms stars, controls orbits, etc.
c) graviton (theoretical, not yet discovered)

Weak Nuclear Force
a) Acts on particles with the "flavour charge".
b) Controls radioactive decay reactions.
c) W & Z particles

Electromagnetism
a) Acts on anything with electric charge.
b) Involved in all electrical & magnetic phenomena including EMR, electronics, chemical bonding, etc.
c) photon

Strong Nuclear Force
a) Acts on particles with "colour charge" (quarks).
b) Holds quarks together to form nuclear particles = protons, neutrons & mesons.
c) gluon

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Answer Section

Worksheet 14 (cont.)

2.

a) At extreme high energies, such as the early Big-Bang, the fundamental forces may be all one single force. At lower energies, the forces separate and appear to be different.

b) Electricity & magnetism were "unified" by Maxwell in 19th century. Electromagnetism & the weak nuclear force were unified in 1970's.

c) Electroweak may soon be unified with the strong force. This would be the GUT = "grand unified theory".
The ToE ("theory of everything") would be if gravity could then be unified with the others. So far, gravity cannot be reconciled with Quantum Physics.

3.

a) Protons contain 3 quarks which have charge +2/3, +2/3, -1/3 = +1.
Neutrons contain 3 quarks which have charge +2/3, -1/3, -1/3 = 0

b) A type of "gauge boson" called "gluon".

c) Protons & neutrons are held together in a nucleus by interactions with mesons. In both cases, the force acts over very short distances and its strength can be related to the "mass defect" within a nucleon, or entire nucleus.

d) If an atomic nucleus suffers a high energy collision, several types of mesons may be liberated. Outside the nucleus, mesons are unstable and rapidly decay into a variety of other particles, including anti-particles. This cascade of different particles was very confusing in early studies of cosmic rays & with particle accelerators.

4.

a) Leptons are fundamental particles with very small mass and carry "flavour charge". Best known is the electron which also has electric charge. The various neutrinos have no electrical charge.

b)
Their mass (although small) means they feel gravity.

Flavour charge means they feel the weak nuclear force & are often involved in radioactive decay.

Those with electric charge (eg electron) interact electromagnetically.

Leptons have no "colour charge" so they do not feel the strong nuclear force and are not at home within the nucleus. If formed within a nucleus by a radioactive decay, they immediately leave at high speed... eg beta particle & anti-neutrino.

5.

a) An anti-particle is like a "mirror image" of a particle. It has the same mass, but is opposite in all its quantum properties. eg opposite electric charge. For example, a positron is an anti-electron, with +1 electric charge.

b) They will annihilate each other. Total mass will be converted to gamma rays according to $E = mc^2$.