WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 3

PHYSICS



EXAM QUESTION PACK

3.8 NUCLEAR ENERGY

SCORE	PERCENTAGE
/69	%

STEMUP

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#1

7. *(a)* Explain briefly what is meant by conservation of mass-energy. [2]

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(b) It is suggested that a collision between two protons, each of kinetic energy 3 GeV produces the following interaction:

$$p + p \longrightarrow 5p + 3\bar{p} + n + \bar{n} + 2\pi^{+} + 2\pi^{-} + 4\nu_{e}$$

Determine which, if any, of the conservation laws are violated (the rest mass-energy of a proton or a neutron ≈ 1 GeV). [4]

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Question taken from Eduqas examination paper 842103, June 2018

#2

Discuss the make-up and properties of the following particles e^-, e^+, n, $\overline{p}$, π^-. [6 QER]

Question taken from Eduqas examination paper 842103, November 2020

#3

6. *(a)* The anti-Δ^{++} is an anti-baryon and a first-generation particle which has a charge of $-2e$. Explain why the only possible quark make-up of the anti-Δ^{++} is $\bar{u}\bar{u}\bar{u}$. [1]

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(b) The anti-Δ^{++} has a lifetime of approximately 6×10^{-24} s and decays into a π meson and another anti-baryon. Deduce the quark make-up of the π meson and the anti-baryon and name them. [2]

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(c) State which force is responsible for the decay of the anti-Δ^{++} into a π meson and anti-baryon, giving a reason for your answer. [2]

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(d) In 2011, a highly respected international research collaboration reported that they had measured neutrinos travelling at speeds greater than that of light. This report was met by caution from the scientific community and then the result was disproved. Explain briefly why the result was met with caution and how the results might have been disproved. [3]

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Question taken from Eduqas examination paper 842103, June 2019

#4

When colliding two protons at very high energy the following interaction has been observed at the large hadron collider in CERN.

$$p + p \rightarrow {}^{2}_{1}H + e^{+} + x$$

(a) Use the conservation of lepton number and conservation of charge to identify the particle x. [3]

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(b) State which force is responsible for this interaction. Give your reasoning. [2]

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(c) State which of the above particles can be classed as: [2]

(i) a baryon;

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(ii) an antiparticle.

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(d) At present, countries in Europe contribute to funding research at CERN. Evaluate whether or not the money could be better spent on humanitarian aid. [2]

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Question taken from Eduqas examination paper 842001, June 2017

#5

7. *(a)* Quarks and electron neutrinos are fundamental particles whereas protons and neutrons are not. Explain this statement. [2]

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(b) (i) State why it is that electron neutrinos are very difficult to detect. [2]

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(ii) Electron neutrinos can be detected when they interact with deuterium nuclei, ${}^{2}_{1}\mathrm{H}$, that are present in heavy water. The following reaction is observed.

$$\nu_e + {}^{2}_{1}\mathrm{H} \rightarrow \mathrm{p} + \mathrm{p} + \mathrm{x}$$

Identify particle x and justify your answer using the conservation laws. [3]

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(c) When a positron and an electron meet they annihilate to produce two gamma ray photons.

$$e^{+} + e^{-} \rightarrow \gamma + \gamma$$

State which force is responsible for this interaction, giving your reasoning. [2]

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Question taken from Eduqas examination paper 842001, June 2019

#6

5. *(a)* Subatomic particles can be classified as either hadrons or leptons. Giving examples of each, fully describe the differences and similarities between these two groups. Include the types of interaction they undergo and how one of the groups can be further sub divided. [6 QER]

(b) Electron capture occurs when an electron interacts with a proton in the nucleus of an atom. The following interaction occurs:

$$p + e^- \longrightarrow n + x$$

(i) Identify the particle, x, explaining how you used the relevant conservation laws. [3]

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(ii) Describe the change in quark flavour during electron capture. [1]

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(iii) State and explain which interaction is responsible for this decay. [1]

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Question taken from Eduqas examination paper 842001, June 2018

#7

(a) A carbon-14 nucleus decays as shown:

$$^{14}_{6}C \longrightarrow {}^{14}_{7}N + e^{-} + \bar{\nu}_e$$

(i) Show how charge, baryon number and lepton number are conserved in this decay. [3]

(ii) Give two reasons why this must be a weak nuclear force interaction. [2]

(b) The decay constant of carbon-14 is $3.83 \times 10^{-12}\ s^{-1}$.

(i) Calculate its half-life in years. [3]

(ii) The natural ratio of carbon-14 to carbon-12 is 1.00×10^{-12} i.e.

$$\frac{\text{number of } ^{14}_{6}C \text{ nuclei}}{\text{number of } ^{12}_{6}C \text{ nuclei}} = 1.00 \times 10^{-12}$$

Calculate the activity of 12 g of naturally occurring carbon. [3]

(iii) In an old tree found preserved in a peat bog in Ireland, much of the carbon-14 has decayed but the carbon-12 all remains. The ratio of carbon-14 to carbon-12 in this old tree has dropped to 0.34×10^{-12}. Calculate the age of the old tree. [3]

(c) Carbon-11 ($^{11}_{6}C$) is proton rich and undergoes positron decay to a stable isotope of boron (B). Complete the following decay equation for carbon-11. Space is provided should you require analysis of lepton number, baryon number and charge. [3]

$$^{11}_{6}C \longrightarrow$$

(d) On the 14 March 2013, the discovery of the Higgs boson was first announced by CERN. Some physicists were convinced that they had discovered the Higgs boson, others believed that there are many different types of Higgs bosons while others claim that this was just another particle and not the Higgs boson. Explain how it may or may not be decided which, if any, of these claims is correct. [3]

Question taken from Eduqas examination paper 842103, June 2017

Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)		Mass can be converted to energy (or vice versa or $E = mc^2$) (1) So mass-energy cons used if change of mass (1) i.e. short concluding comment stating briefly mass-energy conservation (rather than simple energy conservation) also accept $m_0c^2 + E$ conserved (or similar)	2			2		
	(b)		Baryon number OK [1+1 = 5-3+1-1+0+0+0] or 2=2 (1) Accept U and D conservation : 4U + 2D = 4U + 2D Or Quark number: 6 = 6 Lepton number not OK [0+0 ≠ 0+0+0+0+0+0+4] or 0≠4 (1) Charge conservation OK [1+1 = 5-3+0+0+2-2+0] or 2=2] (1) Mass energy not OK not enough energy to produce products (1) If not 4 correct conclusions 3max.			4	4		
			Question 7 total	**2**	**0**	**4**	**6**	**0**	**0**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			Indicative content: 1. Names - electron, positron (anti-electron), neutron, anti-proton, pion/pi meson 2. Fundamental/composite - electron&positron fundamental others not 3. Leptons - electron & positron (anti-lepton) OR lepton numbers 4. Hadrons - neutron, anti-proton & pion 5. Baryons & mesons - neutron (B), anti-proton (anti-baryon), pion - meson OR baryon numbers 6. Quarks - neutron - 3 quarks, anti-proton - 3 anti-quarks, pion - quark + anti-quark 7. Strong force - felt by hadrons or quarks only 8. Weak force - felt by all particles OR accept leptons 9. E-M force - felt by all charged particles 10. Make-up - udd, $\overline{\mathbf{uud}}$, $\overline{\mathbf{ud}}$ 11. Charge - -1, +1, 0, -1, -1 12. Anti-particles - positron for electron and anti-proton mentioned	6			6		
			5-6 marks 7-12 points – all particles considered There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** 3-6 points – majority of particles considered There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure. **1-2 marks** 1-2 points – a few particles considered There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure. **0 marks** No attempt made or no response worthy of credit						
			Question total	**6**	**0**	**0**	**6**	**0**	**0**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	(a)		$-\frac{2}{3}-\frac{2}{3}-\frac{2}{3}=-2$ seen or statement that this is the only way to get a charge of -2(e)		1		1		
	(b)		$\overline{uuu} \rightarrow \overline{uu}\overline{d} + \overline{u}d$ or $\overline{uuu}+u\overline{u}$ or $\overline{uuu}+d\overline{d}$ [1] [any order of quarks in the baryon and meson] Anti-proton or anti- Δ^+ and π^- OR anti- Δ^{++} and π^0 [1]			2	2		
	(c)		Strong force [1] **no ecf** Short time **or** conservation of u and d **and** no photon or accept ONLY quarks / hadrons involved **or** no neutrinos **and** no photons **or** no flavour change **and** no photons [1]			2	2		
	(d)		**Any 3 × (1) valid points:** -contradicts current theories (relativity) or can't travel faster than the speed of light ✓ -current theories well established ✓ -further experiments ✓ -by other groups / scientists / peer review ✓ -due to instrument problems (timing delay) / systematic errors ✓			3	3		
			Question 6 total	**0**	**1**	**7**	**8**	**0**	**0**

#4

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		0 +0 = 0 -1 [+1] [Lepton conservation] (1) +1 +1 = +1 +1 [+0] [Charge conservation] (1) Neutrino (1)		1 1	1	3		
	(b)		Weak (1) Presence of neutrino / change of quark flavour (1)	2			2		
	(c)	(i)	Proton / p / ^2_1H	1			1		
		(ii)	Positron / e^+ Allow anti-electron	1			1		
	(d)		Any 2 ×(1) from: • Economic argument given e.g. money better spent on welfare / health etc • Scientific consequence discussed e.g. need to know origin of universe • Benefits to mankind from advanced research / new technologies • Scientific investment generates money			2	2		
			Question total	**4**	**2**	**3**	**9**	**0**	**0**

#5

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)		Protons and neutrons are each made up of 3 quarks (1) Quarks and neutrinos are not made up of other particles (1)	2			2		
	(b)	(i)	No strong force / no electromagnetic force /only interact by weak force (1) They are uncharged (1)	2			2		
		(ii)	Conservation of charge 0 + 1 → 1 + 1 **–1** (1) Conservation of lepton 1 + 0 → 0 + 0 + **1** (1) x is an electron (1)		1 1	1	3		
	(c)		Electromagnetic (1) Presence of photons / gamma rays (1)		1	1	2		
			Question 7 total	**4**	**3**	**2**	**9**	**0**	**0**

#6

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*		**Differences** **Hadrons** H1 Made up of quarks H2 Affected by strong interaction H3 e.g. protons / neutrons / mesons **Leptons** L1 Fundamental particles L2 Not affected by strong interaction L3 e.g. electron / electron neutrino **Similarities** S1 Both have a rest mass / gravitational attraction S2 Both can be affected by the weak interaction S3 Both can be affected by the electromagnetic interaction **Sub group** G1 Hadrons can be split into Baryons and mesons G2 Baryons contain 3 quarks G3 Mesons contain a quark antiquark pair **5 – 6 marks** 2 points from each of H L S and G *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3 – 4 marks** 1 point from each of H L S and G *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1 – 2 marks** 3 points from any group *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*	6			6		
	(b)	(i)	Charge +1 -1 = 0 + 0 (1) Lepton number 0 +1 = 0 +1 (1) Hence, x is an uncharged lepton, … … Hence Particle identified as an electro neutrino (1)		3		3		
		(ii)	u changes to d / uud to udd		1		1		
		(iii)	Weak interaction because of the presence of a neutrino / change in quark flavour	1			1		
			Question 5 total	**7**	**4**	**0**	**11**	**0**	**0**

#7

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	Charge: 6 = 7 -1 + 0 **or** 0 = 1 - 1 + 0 **or** $-\frac{1}{3}=\frac{2}{3}-1+0$ (1) Baryon number: 14 = 14 + 0 + 0 **or** 1 = 1 + 0 + 0 **or** $\frac{1}{3}=\frac{1}{3}+0+0$ **or** 42 = 42 + 0 + 0 (1) Lepton number: 0 = 0 + 1 – 1 **or** 6 = 6 + 1 – 1 (1)		3		3		
		(ii)	Change of quark flavour [from d to u] (1) Neutrino involved accept symbol (1) Accept long half-life		2		2		
	(b)	(i)	Use of the equation $T_{\frac{1}{2}}=\frac{\ln 2}{\lambda}$ (1) $T_{\frac{1}{2}} = 1.81 \times 10^{11}$ [s] (1) 5 730 [year] (1)	1	1 1		3	3	
		(ii)	Use of the equation $A = \lambda N$ (1) Method for obtaining N correct ($6.02 \times 10^{23} \times 1 \times 10^{-12}$) (1) Answer = 2.30 Bq **unit mark** (1)	1	1 1		3	3	
		(iii)	$0.34 \times 10^{-12} = 1 \times 10^{-12} e^{-\lambda t}$ i.e. substitution or into $\frac{1}{2^n}$ (1) Taking logs correctly e.g. $\log A = \log A_0 - \lambda t$ (1) 2.82×10^{11} [s] or 8 900 [year] (1)	1	1 1		3	3	
	(c)		11, 5 for boron (1) Positron symbol correct e.g. e+ or beta + (1) Neutrino symbol correct (ν_e) but accept ν (1) Any fourth particle added lose 1 mark		1	1 1	3		
	(d)		**Any 3 × (1) from:** • cannot tell who is correct or words to that effect • further experiments or research must be carried out • experiments at higher (collision) energies (to find other particles) / bigger or better colliders • time/history will (probably) show who was correct • further theory / theoretical research • reference to the Higgs behaving as expected or not as expected • those who claim not should suggest an alternative • Higgs thought to be detected with 5σ [confidence] **Don't accept** any reference to charge or baryon number or lepton number conservation			3	3		
			Question total	**3**	**12**	**5**	**20**	**9**	**0**