T7-1 *[255 marks]*

1. *[1 mark]*

Markscheme

A

Examiners report

Response B with many particles being significantly deflected was a common choice of candidates at both levels; A shows the clear majority of particles passing through the foil undeflected.

2. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

3. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

4. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

5. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

6a.

[7 marks]

Markscheme

(i) difference in total mass of individual nucleons and nucleus / energy needed to divide nucleus into component nucleons / energy liberated when nucleus formed from component individual nucleons;

nuclear binding energy is the energy equivalent of mass defect / reference to $E=mc^2$;

(ii) S marked near line between 50 and 70;

(iii) binding energy per nucleon read from graph as 1.1/1.2 and 7.1/7.2 (MeV);

both values multiplied by 4;

difference given between 23.6 and 24.4 (MeV);

3.8×10^{-12}(J) **or** 3.9×10^{-12} (J);

Examiners report

(i) The definition of either mass defect or nuclear binding energy was badly understood and there were many confused answers to this part. As in previous years the most common misunderstanding amounts to candidates believing that the nuclear binding energy is the energy that holds the nucleons together in the nucleus.

(ii) The majority of candidates labelled the most stable region within tolerance. A minority appear to have missed this part of the question and not answered it at all – candidates should be reminded to read the paper carefully and not to throw away marks by speed reading.

(iii) For a straightforward nuclear energy question this part was poorly answered. It was quite common to see candidates ignoring the fact that two deuterons were fusing to produce helium. As a 'show that' question, it is important that candidate do produce a final answer that is to more than the one digit approximation – many were satisfied by setting out the calculation and then immediately approximating to 4pJ without showing that this was the case. This will always lose a mark in such questions

6b.

[7 marks]

Markscheme

(i) ${}^{1}_{1}\mathrm{H}$ / ${}^{1}_{1}\mathrm{p}$;
${}^{2}_{3}\mathrm{He}$;
${}^{0}_{-1}\mathrm{e}$ / ${}^{0}_{-1}\beta$;
${}^{0}_{0}\overline{\upsilon}$; *(do not allow neutrino)*

(ii) recognition that fusion process is more likely (at high temperatures);

the (electric) force between nuclei is repulsive;

nuclei need ~ 10^{-15} m separations for strong force to act;

kinetic energy of nuclei increases with temperature;

(higher temperature) increases probability of nuclear collisions;

radioactive decay is unaffected by temperature;

*Award **[0]** for correct choice with no or wrong explanations.*

Examiners report

(i) This part was quite well done by many candidates with the proton (in the first equation) and the electron or antineutrino (in the second equation) being the most common omissions or having mistakes in the proton or nucleon numbers.

(ii) Few candidates completed this well. Most did no more than to make a statement and it was uncommon for candidates to state that the beta decay is temperature independent. The best answers explained that the deuterium nuclei needed high kinetic energies to be able to approach each other and overcome the Coulombic repulsion and allow the strong nuclear force to come into play.

7a. *[3 marks]*

Markscheme

atomic spectra have discrete line structures / only discrete frequencies/wavelengths;
photon energy is related to frequency/wavelength;
photons have discrete energies;
photons arise from electron transitions between energy levels;
which must have discrete values of energy;

Examiners report

(a) Candidates struggled with this question. Although they demonstrated some familiarity with the idea, they could not clearly describe the connection between atomic structure and the emission spectra, usually discussing electrons without photons. The arguments leading from atomic spectra to energy levels were not logically organised.

7b. *[3 marks]*

Markscheme

de Broglie suggests that electrons/all particles have an associated wavelength; this wave will be a stationary wave which meets the boundary conditions of the box; the stationary wave has wavelength $\frac{2L}{n}$ (where L is the length of the box and where n is an integer);

Examiners report

There were very few correct answers to (b).

7c. *[6 marks]*

Markscheme

(i) wavelength of ψ_A larger than ψ_B;
therefore momentum of ψ_B larger than ψ_A (from de Broglie hypothesis); therefore ψ_B has larger energy;
*Award **[1 max]** for a bald correct answer.*

or

ψ_B has n=3, ψ_A has n=2;
$E_K \propto n^2$;
so ψ_B corresponds to the larger energy;

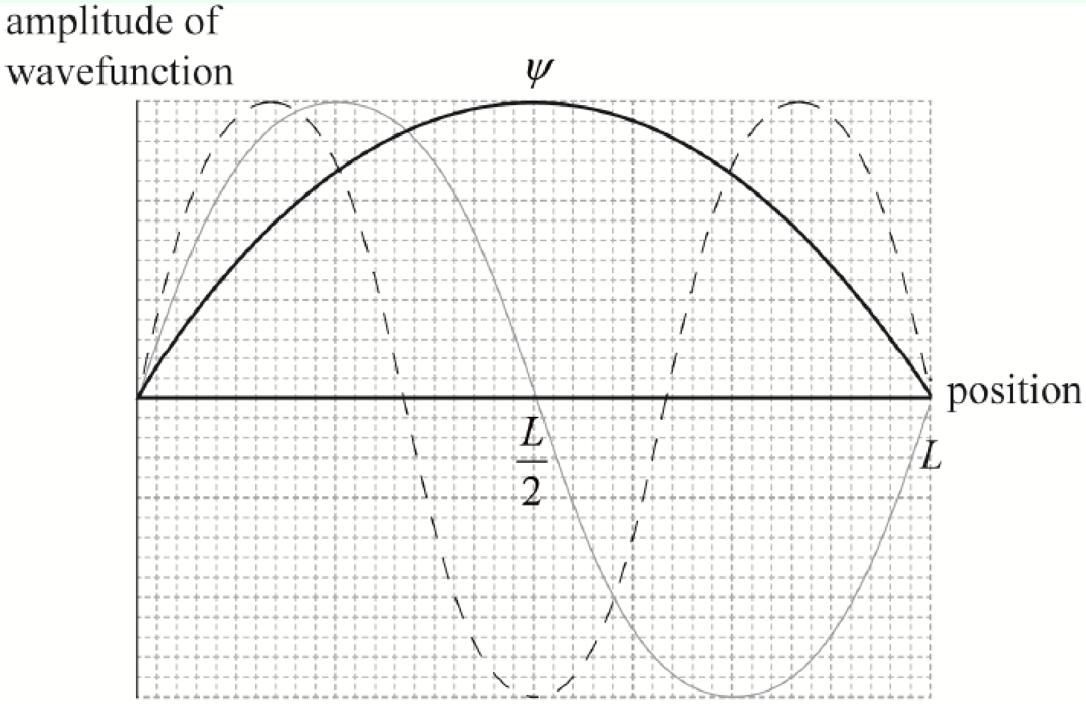
(ii) ψ_A=0, $\psi_B \neq 0$ in the middle of the box/at $\frac{L}{2}$;
so ψ_B corresponds to the larger probability since probability $\propto |\psi|^2$;
Accept $\propto \psi^2$.

or

the probability (of finding the electron) is related to the amplitude;
amplitude of ψ_B is greater than amplitude of ψ_A so ψ_B is more likely to be found;

*Award **[1 max]** for a bald correct answer.*

(iii)



correct sketch; (accept -ψ)
Accept wavefunction with any amplitude.

Examiners report

(i) was reasonably well done by many, although many did not refer to the de Broglie hypothesis explicitly and thus relate wavelength to momentum and so to energy.

(ii) was poorly answered. Not many candidates understood the relation between amplitude and probability of locating the particle.

(iii) was well done by most.

8a. *[3 marks]*

Markscheme

$^{22}_{11}\text{Na} \rightarrow ^{22}_{10}\text{Ne} + ^{0}_{+1}e + ^{0}_{0}v$

$^{22}_{10}\text{Ne}$;

$^{0}_{+1}e$ (*accept* $^{0}_{+}e$)

$^{0}_{0}v$; (*award* ***[0]*** *for* $^{0}_{0}\overline{v}$)

Examiners report

This question was well done in general.

8b. *[1 mark]*

Markscheme

time taken for half/50% of the nuclei to decay / activity to drop by half/50%;

Examiners report

Many candidates referred to mass halving rather than activity.

8c. *[4 marks]*

Markscheme

(i) $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$;

$\frac{0.693}{0.27\text{yr}^{-1}}$=2.6 (years);

Award ***[2]*** *for a bald correct answer.*

(ii) N=5.0 x 10^{23} x $e^{-0.27\times5.0}$;

N=1.3 x 10^{23};

Award ***[2]*** *for a bald correct answer.*

Examiners report

9a. *[2 marks]*

Markscheme

(i) nuclides/atom/element/nucleus/nuclei that have different nucleon/neutron numbers but same proton number/are same element / *OWTTE;*

(ii) the time taken for the activity (of a radioactive sample) to decrease by half / the time taken for half the (initial) number of radioactive nuclei/atoms/mass to decay; *("radioactive" must be seen in alternative answer)*

Examiners report

(i) Although many were able to give a correct statement of the meaning of the term isotope there were a disappointing number who could not. In general, candidates should attempt to give clearer, more succinct definitions.

(ii) Equally, definitions of radioactive half-life were often weak, incomplete and confused, referring to the amount or mass of the total (rarely initial) substance rather than its activity. These are straightforward definitions to memorize and candidates would be well advised to spend time on this routine task.

9b. *[3 marks]*

Markscheme

(i) 2;

(ii) (mass difference=)7.0160 – [3.0161+ 4.0026]= (–)2.7x 10^{-3}u;
(energy required=)(–)2.7x10^{-3}x931.5 ***or*** 2.5151(MeV) ;
(≈ 2.5 MeV)

Allow unit conversions via mass and mc^2 .
Must see either answer to 3+sf or subtraction or use of mc^2 to award 2^{nd} mark.

Examiners report

(i) The proton number was almost invariably correct.

(ii) All the basics of this question were understood, the calculation was not well completed by many. Candidates need to understand that to gain full credit in response to “show that” they must convince the examiner that all steps are shown. This is best done by taking the calculation through to at least one more significant figure than is quoted in the question and explaining each line of calculation in words. Even strong candidates are not as careful as they could be about this.

9c. *[2 marks]*

Markscheme

2.5MeV must be converted to mass (in the interaction) / otherwise the products would not be moving;
(to conserve momentum) final products must have total momentum equal to that of incoming neutron (so extra energy is required) / *OWTTE;*

Examiners report

This was another question where the candidates needed to articulate a logical argument. It was extremely poorly done. It would seem that candidates are muddled between the concepts of energy and momentum. There were attempts to gain a mark but candidates did not consider in the first instance why the neutron energy has to be greater than 2.5 MeV. This should not have been beyond the more able SL candidate.

9d. *[2 marks]*

Markscheme

$^3_1\mathrm{H} \rightarrow {}^3_2\mathrm{He} + \beta^- + \bar{v}$
β^- or ${}^{0}_{-1}\mathrm{e}$ **or** e^- **or** electron **or** beta particle;
$\bar{v}$ **or** ${}^0_0\bar{v}$ **or** antineutrino;
Allow answers in either order.

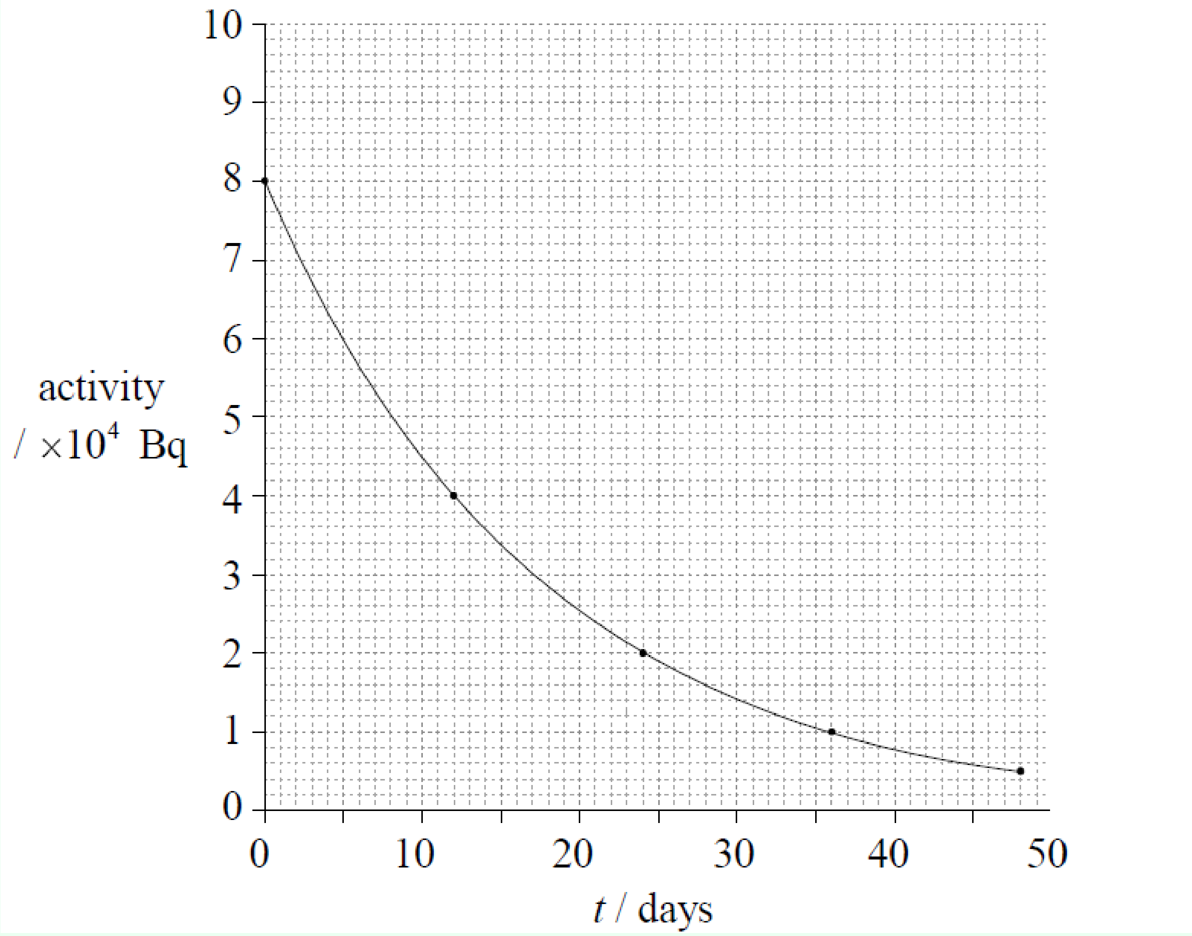
Examiners report

Failure to recognize that the antineutrino not the neutrino is produced marred this normally well-answered question.

9e. *[5 marks]*

Markscheme

(i)



five correct data points;
smooth curve through data points;
Do not allow ECF if incorrect points are plotted leading to a non-smooth curve.
Award full credit for correct curve even if the data points are not visible.

(ii) 1.4×10^4 (Bq);
Allow correct reading from mis-drawn graph
$\pm$ *0.1.*

(iii) number of atoms left= $\frac{1.2\times10^{11}\times1.4}{8}$ ***or*** uses proportion ***or*** uses ln $\left(\frac{N}{N_0}\right) = -\lambda t$; *(with correct values)*
2.1×10^{10};
*Award **[2]** for a bald correct answer.*

Examiners report

[N/A]

10a. *[1 mark]*

Markscheme

particle with no internal structure / cannot be broken down further;

Examiners report

This question was well answered.

10b. *[3 marks]*

Markscheme

(i) pion/meson/gluon;

(ii) $m = \frac{h}{4\pi Rc}$;

1.8×10^{-28}(kg);

Examiners report

This question was well answered.

11a. *[1 mark]*

Markscheme

-3;

Examiners report

Many candidates knew about the idea of strangeness, but did not assign a numerical value.

11b. *[2 marks]*

Markscheme

(i) anti u (quark) /$\bar{u}$;
(ii) W^-;

Examiners report

Was reasonably well answered.

11c. *[2 marks]*

Markscheme

principal maxima broaden;

secondary maxima appear;

Examiners report

There were almost no correct answers. Candidates clearly need a lot of practice answering questions on the diffraction grating.

12. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

13.

[1 mark]

Markscheme

C

Examiners report

[N/A]

14.

[2 marks]

Markscheme

(i) particle with no internal structure / cannot be broken down further;

(ii) Electron / neutrino / any lepton / any named exchange particle;

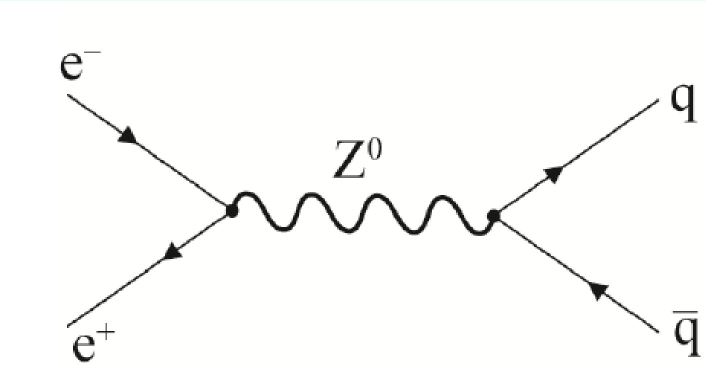
Examiners report

Well answered although many answers just said “lepton” in (ii) without naming it.

15.

[2 marks]

Markscheme



correct incoming and outgoing particles with correct arrow direction;
Z^0 shown correctly;
Allow any consistent labelling for quark pair.

Examiners report

Were reasonably well answered

16.

[3 marks]

Markscheme

(i) S = -3;
(ii) baryon;
to conserve baryon number / has structure sss;

Examiners report

(a)(i) a strangeness = -3 was usually correctly given, as was the identification of X as a baryon.

17a.

[2 marks]

Markscheme

${}^{137}_{56}\mathrm{Ba}$;
anti-neutrino / $\bar{v}$;

Examiners report

[N/A]

17b.

[2 marks]

Markscheme

evidence of use of 4 half-lives;
so 0.938 ***or*** 93.8% ***or*** $\frac{15}{16}$ decays;

Examiners report

[N/A]

17c.

[2 marks]

Markscheme

reference to a short-term effect e.g. skin reddening / burning;
reference to a long-term effect e.g. genetic damage / cancer;
reference to relative penetrative power of beta/ionizing power compared to alpha or gamma;

Examiners report

[N/A]

18a.

[3 marks]

Markscheme

shine white light through;
a tube of the gas;
then observe with spectroscope/grating/prism;

Examiners report

[N/A]

18b.

[4 marks]

Markscheme

(i) continuous spectrum crossed by dark lines;

(ii) dark lines formed by the absorption of photons;
the absorbed photons have specific/discreet wavelengths;
indicating discreet differences in energy;
which can only be explained by existence of energy levels;

Examiners report

[N/A]

18c. *[3 marks]*

Markscheme

$E = 13.6\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = 12.1\text{eV}$;

12.1eV=12.1×1.6×10^{-19}J $=\frac{hc}{\lambda}$;

λ=102nm ***or*** 103nm;

*Award **[3]** for a bald correct answer.*

Examiners report

[N/A]

19a. *[2 marks]*

Markscheme

neutrino/ν;

positron / e^+ / ${}^{0}_{+1}e$ / β^+;

*Award **[1 max]** for wrongly stating electron and antineutrino. Both needed for the ECF.*

Order of answers is not important.

Examiners report

[N/A]

19b. *[3 marks]*

Markscheme

$\lambda = \left(\frac{\ln 2}{1.3\times10^9} =\right) 5.31\times10^{-10}\text{yr}^{-1}$;

$0.15 = e^{\left[-5.31\times10^{-10}\times t\right]}$;

t=3.6×10^{9}yr;

*Award **[3]** for a bald correct answer.*

or

(0.5)^n=0.15;

$n = \frac{\log(0.15)}{\log(0.5)} = 2.74\text{half} - \text{lives}$;

2.74×1.3×10^9=3.6×10^{9}yr;

*Award **[3]** for a bald correct answer.*

Examiners report

[N/A]

19c. *[2 marks]*

Markscheme

the count rate/activity of a sample;

the mass/number of atoms in the sample;

Examiners report

[N/A]

20.

[1 mark]

Markscheme

B

Examiners report

21.

[1 mark]

Markscheme

B

Examiners report

22.

[1 mark]

Markscheme

A

Examiners report

[N/A]

23.

[1 mark]

Markscheme

C

Examiners report

[N/A]

24.

[1 mark]

Markscheme

C

Examiners report

[N/A]

25.

[1 mark]

Markscheme

D

Examiners report

This was outside the requirements of the syllabus, as many teachers observed, and the question was discounted.

26a. *[3 marks]*

Markscheme

(i) *nuclide:*
(a species of atom that is characterized by) the constitution of its nucleus /the number of protons and neutrons in the nucleus OWTTE;
isotope:
nuclides with the same proton number but different nucleon/neutron numbers;
or
atoms of the same element that have different numbers of neutrons/neutron number;
(ii) alpha particle / helium nucleus / ${}^{4}_{2}\mathrm{He}$;

Examiners report

(i) A good statement of the meaning of *nuclide* was rare. *Isotope* was much better understood and explained.

(ii) The majority identified the alpha particle as the other particle in the reaction. Common errors included the neutron, various forms of neutrino, and the previously unknown alpha photon.

26b. *[3 marks]*

Markscheme

protons repel/break nucleus apart;
binding energy/strong force holds nucleus together;
neutron excess / n:p ratio is greater in lead therefore overall balance of forces is more attractive / (magnitude of) binding energy per nucleon is greater in lead / binding energy per nucleon more negative in lead than uranium;

Examiners report

Candidates found it difficult to explain why U-235 is more unstable than a stable isotope of lead. It was rare to see clear statements of repulsive nature of the coulomb force and that it acts between protons whereas the strong nuclear force is attractive so that the balance of proton: neutron is changed in the more stable lead. Explanations in terms of binding energy per nucleon were also accepted. Explanations couched in terms of binding energy alone were usually incorrect.

26c. *[3 marks]*

Markscheme

$\Delta m = 235.04393 – [143.922952 + 88.91763 + 2 \times 1.00867]$;
$=0.1860$u; (*must see the u to award this mark*)
energy$=0.1860 \times 931.5 = 173.9$ MeV;
($\approx$ 200 MeV)

Examiners report

SL only Calculations of the kinetic energy of the fission products in a nuclear reaction were carried through competently by many. Some however failed to show clearly the conversion from atomic mass units to electronvolts and lost some credit for this.

27. *[1 mark]*

Examiners report

[N/A]

28.

[1 mark]

Markscheme

C

Examiners report

It must be known that a unit for mass that is convenient in atomic and nuclear physics is $MeVc^{-2}$.

29.

[1 mark]

Markscheme

A

Examiners report

[N/A]

30.

[1 mark]

Markscheme

C

Examiners report

[N/A]

31.

[1 mark]

Markscheme

D

Examiners report

[N/A]

32a.

[3 marks]

Markscheme

emission of (alpha/beta/gamma) particles/photons/electromagnetic radiation;
nucleus becomes more (energetically) stable;
constant probability of decay (per unit time);
is random process;
activity/number of unstable nuclei in sample reduces by half over constant time intervals/exponentially;
not affected by temperature/environment / is spontaneous process;

Examiners report

[N/A]

32b.

[7 marks]

Markscheme

(i) 93;

(ii) mass of products is less than mass of reactants / there is a mass defect;
mass is converted into energy (according to equation $E=mc^2$);

(iii) the (minimum) energy required to (completely) separate the nucleons in a nucleus / the energy released when a nucleus is assembled from its constituent nucleons;

(iv) calculation of binding energies as shown below;

americium-241 = 241×7.54=1817.14 MeV
neptunium-237 = 237×7.58 = 1796.46 MeV
helium-4 = 4×7.07 = 28.28 MeV

energy released is the difference of binding energies;
and so equals 7.60 MeV;

*Award **[2 max]** for an answer that multiplies by the number of neutrons or number of protons.*
Ignore any negative sign in answer.

Examiners report

[N/A]

33a.

[2 marks]

Markscheme

all particles have an associated wavelength / *OWTTE;*

wavelength is given by $\lambda = \frac{h}{p}$, where *h* is Planck's constant and *p* is momentum;

Examiners report

[N/A]

33b.

[3 marks]

Markscheme

from de Broglie hypothesis, $p_n = \frac{h}{\lambda_n} = \frac{nh}{2L}$;
kinetic energy given by $E_K = \frac{p^2}{2m_e}$;
combined and manipulated to obtain result;

Examiners report

[N/A]

33c.

[4 marks]

$$\lambda = \frac{2L}{n} = \frac{2\times1.0\times10^{-10}}{1} = 2.0\times10^{-10}$$
$$p = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{2.0\times10^{-10}} = 3.3\times10^{-24}\text{kgms}^{-1}$$

$$\Delta x\Delta p \geq \frac{h}{4\pi}$$
$$\Delta p \geq \frac{6.6\times10^{-34}}{4\pi\times0.5\times10^{-10}} = 1.1\times10^{-24}\text{kgms}^{-1}$$

Examiners report

[N/A]

34a. *[2 marks]*

Markscheme

exchange particles are virtual particles/bosons;
that mediate/carry/transmit the weak/strong/em force between interacting particles / *OWTTE*;
Award first marking point for named bosons also, e.g. photons, W, Z, gluons.

Examiners report

[N/A]

34b. *[2 marks]*

Markscheme

strangeness in initial state is –1 and zero in the final;
hence it is not conserved;

*Award **[0]** for unsupported second marking point.*

Examiners report

[N/A]

34c. *[2 marks]*

Markscheme

$\Delta t \approx \frac{h}{4\pi \Delta E} = \frac{6.63\times10^{-34}}{4\pi\times1.2\times10^{9}\times1.6\times10^{-19}}$;
$\Delta t \approx 3\times10^{-25}\text{s}$;

Examiners report

[N/A]

34d. *[2 marks]*

Markscheme

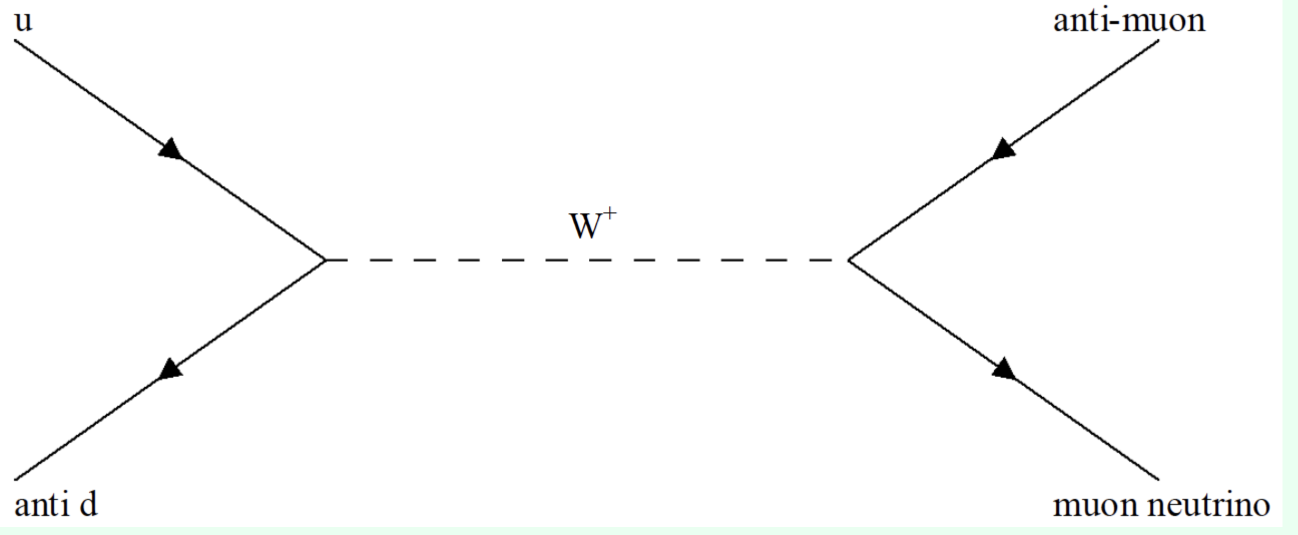


diagram as above;
correctly labelled W^+;

Allow time to run vertically. Allow particle symbols. Ignore missing or wrong arrow directions.

Examiners report

[N/A]

35. *[5 marks]*

Markscheme

(i) spectral lines are discrete;
therefore energy of photon is discrete/quantized;
photon energy is equivalent to difference in energy that electron has in each (discrete) level / *ΔE* = *hf* / *OWTTE*;
(so electron levels are themselves discrete)

(ii) difference in energy = $hc\left[\frac{1}{\lambda_\gamma}-\frac{1}{\lambda_\alpha}\right]$;
$=6.6\times10^{-34}\times3\times10^{8}\times10^{7}\times0.0780=1.54\times10^{-19}$J;

or

$E_\alpha=\left[\frac{hc}{\lambda_\alpha}\right]=\frac{6.6\times10^{-34}\times3\times10^{8}}{6.56\times10^{-7}}=3.02\times10^{-19}\,\text{J}$ ***or*** 1.89eV
$E_\gamma=\left[\frac{hc}{\lambda_\gamma}\right]=\frac{6.6\times10^{-34}\times3\times10^{8}}{4.34\times10^{-7}}=4.56\times10^{-19}\,\text{J}$ ***or*** 2.85eV {*(both needed for the mark)*
difference in energy=1.54×10^{-19}J ***or*** 0.963 eV;

Examiners report

(i) Although a good chain of argument was seen from many, some candidates struggled to relate the diagram to the existence of energy levels. Sometimes this resulted in a description of photon release that was accurate but irrelevant.
(ii) Simple algebraic misconceptions prevented many from obtaining a correct solution. It was common to see a subtraction of the values of the two wavelengths rather than a subtraction of the reciprocals. Candidates who carried both energies through separately scored more highly than those who attempted early subtractions.

36a. *[2 marks]*

Markscheme

the spin number of a boson is an integer value;
the spin of the kaon can be $\frac{1}{2}+\frac{1}{2}=1$ ***or*** $\frac{1}{2}-\frac{1}{2}=0$

Examiners report

36b. *[6 marks]*

Markscheme

(i) *X*: anti-strange quark / $\bar{s}$;
Y: antimuon / μ^{+};

(ii) the process violates strangeness number conservation;
only the weak interaction allows this violation;

or

the decay of the kaon involves a neutrino;
any decay involving the neutrino must take place by the weak interaction;

(iii) *name:* W (boson);
sign: positive;

Examiners report

37a. *[1 mark]*

Markscheme

photon / graviton / Z / Higgs;

Examiners report

[N/A]

37b. *[3 marks]*

Markscheme

(i) K^0 has a strangeness of +1, its antiparticle has strangeness –1 and so are different;
the antiparticle is s, $\bar{d}$ and so is different;

(ii) strangeness is violated in this decay;
this can only happen with the weak interaction;

(iii) Z^0 / Z;

(iv) $R = \left(\frac{h}{4\pi mc} =\right) \frac{6.6\times10^{-34}}{4\times\pi\times1.6\times10^{-25}\times3.0\times10^{8}}$;
R≈10^{-18}m;
*Award **[2]** for a bald correct answer.*

Examiners report

[N/A]

38a. *[1 mark]*

Markscheme

photon / graviton / Z / Higgs;

Examiners report

[N/A]

38b. *[6 marks]*

Markscheme

(i) K^0 has a strangeness of +1, its antiparticle has strangeness –1 and so are different;

the antiparticle is s, $\bar{d}$ and so is different;

(ii) strangeness is violated in this decay;
this can only happen with the weak interaction;

(iii) Z^0 / Z;

(iv) $R = \left(\frac{h}{4\pi mc} =\right) \frac{6.6\times10^{-34}}{4\times\pi\times1.6\times10^{-25}\times3.0\times10^{8}}$;
$R \approx 10^{-18}$m;
*Award **[2]** for a bald correct answer.*

Examiners report

[N/A]

39a. *[2 marks]*

Markscheme

the statement is true only for low energies;
at higher energies the strength of the strong interaction decreases;

Examiners report

[N/A]

39b. *[2 marks]*

Markscheme

in deep inelastic scattering experiments the energy transferred to the constituents of hadrons is very large;
the scattering pattern is consistent with quarks inside hadrons behaving as free particles / the interaction between the constituents is very weak (asymptotic freedom);

Examiners report

[N/A]

39c. *[2 marks]*

Markscheme

there are electrically neutral constituents inside hadrons / there are gluons within hadrons;
quarks come in (three) colours;
quarks are charged particles;

Examiners report

[N/A]

40.

[1 mark]

Markscheme

D

Examiners report

Far too many candidates selected response A, indicating that they had not carefully read the question.

41.

[1 mark]

Markscheme

B

Examiners report

[N/A]

42.

[1 mark]

Markscheme

B

Examiners report

43.

[1 mark]

Markscheme

D

Examiners report

44.

[1 mark]

Markscheme

B

Examiners report

45a.

[1 mark]

Markscheme

1/12th mass of an atom of carbon-12/^{12}C ;

Examiners report

45b.

[1 mark]

Markscheme

(254.1001×931.5 =)236.7(GeVc^{-2}); (*only accept answer in GeV c^{-2}*)

Examiners report

45c.

[4 marks]

Markscheme

(i) proton / hydrogen nucleus / H^+ / ${}_1^1\mathrm{H}$ / ${}_1^1\mathrm{p}$;

(ii) Δm=(16.8383-[3.7428+13.0942]=)0.0013(GeVc^{-2});
energy required for reaction = 1.3 (MeV);
${}_8^{17}\mathrm{O} + \mathrm{X} = (7.68 - 1.3 =)\, 6.4\, (6.38)\, \mathrm{MeV}$; *(allow correct answer in any valid energy unit)*

Examiners report

45d.

[2 marks]

Markscheme

(i) (nuclei of same element with) same proton number, different number of neutrons / *OWTTE*;

(ii) the time for the activity of a sample to reduce by half / time for the number of the radioactive nuclei to halve from original value;

Examiners report

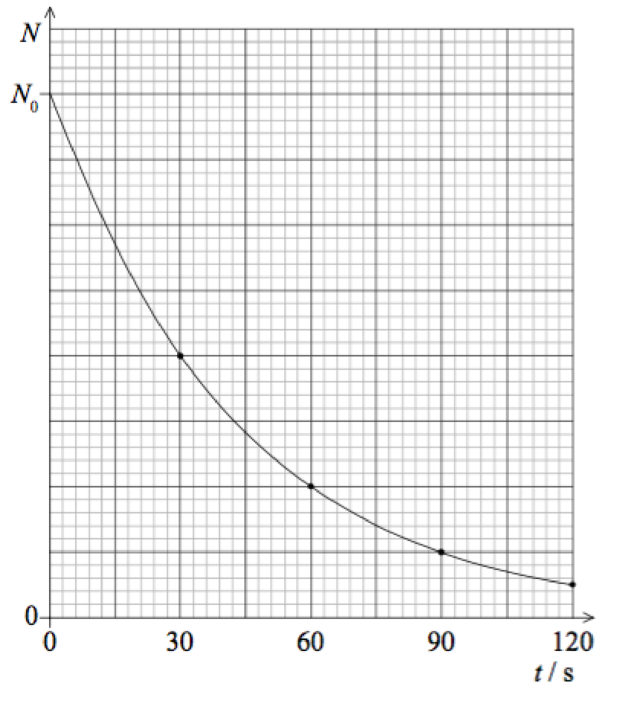
45e.

[2 marks]

Markscheme

scale drawn on *t* axis; (*allow 10 grid squares ≡ 30 s or 40 s*)

smooth curve passes through $\frac{N_0}{2}$ at 30s, $\frac{N_0}{4}$ at 60s, $\frac{N_0}{8}$ at 90s, $\frac{N_0}{16}$ at 120s (to within 1 square); *(points not necessary)*



Examiners report

46.

[5 marks]

Markscheme

(i) number of fusions required per second $= \frac{2.5\times10^{8}}{2.8\times10^{-12}} \left(= 8.93\times10^{19}\right)$;
1 tritium nucleus has mass of 3 amu=3.0×1.67×10^{-27}(kg)(=5.0×10^{-27});
total tritium mass required = 4/4.4/4.5/4.48×10^{-7}(kgs^{-1});
*Award **[3]** for a bald correct answer.*

(ii) *Award any two appropriate problems e.g.*:
difficulty in maintaining high temperature for long periods;
difficulty in maintaining high density of plasma for long periods;
difficulty in enclosing plasma for long periods;
difficulty in controlled removal of heat from plasma;
difficulty in maintaining magnetic fields;

Examiners report

[N/A]

47a.

[4 marks]

Markscheme

(i) refers to unstable nucleus/isotope / refers to spontaneous/random process;
which emits named radiation (from nucleus) / forms different nucleus/isotope;

(ii) combination of two nuclei / *OWTTE*; *(do not allow “particles” or “atoms”)*
to form new nuclide with greater mass/larger nucleus/greater number of nucleons;

Examiners report

[N/A]

47b. *[3 marks]*

Markscheme

$\lambda = \frac{\ln 2}{4500} \left(= 1.54 \times 10^{-4}\right)$;

$0.1N_0 = N_0 \mathrm{e}^{-1.54 \times 10^{-4} t}$;

1.5×10^4(d) ***or*** 1.3×10^9(s);

*Award **[2 max]** if answer is time to lose 10% (680 d).*

Allow answer to be expressed in any time units.

*Award **[3]** for a bald correct answer.*

or

$\ln 0.1 = \frac{-0.69t}{t_{\frac{1}{2}}}$;

t=3.3×4500;

1.5×10^4(d);

*Award **[2 max]** if answer is time to lose 10% (680 d).*

Allow answer to be expressed in any time units.

*Award **[3]** for a bald correct answer.*

Examiners report

[N/A]

47c. *[1 mark]*

Markscheme

${}_0^1n$/neutron;

Examiners report

[N/A]

48. *[4 marks]*

Markscheme

(i) $\frac{6.7 \times 10^{-34} \times 3.0 \times 10^8}{4.9 \times 10^{-7}}$;

2.5 ***or*** 2.6 eV;

(ii) transition between –0.85 and –3.4;

correct direction of arrow (down);

Examiners report

[N/A]

49a. *[2 marks]*

Markscheme

(i) particle that has no internal structure/is not made out of any smaller constituents;

(ii) leptons;

Examiners report

[N/A]

49b. *[6 marks]*

Markscheme

(i) intermediate vector boson/W boson;

(ii) $m = \frac{h}{4\pi Rc}$;

$= \left(\frac{6.6\times10^{-34}}{4\times3.14\times10^{-18}\times3.0\times10^{8}} =\right) 1.75\times10^{-25}\text{kg}$;

$= \frac{1.75\times10^{-25}c^2}{e} = 109\text{GeVc}^{-2} \approx 10^2\text{GeVc}^{-2}$;

(iii) the neutron quark structure is udd and the proton uud;
a d quark in the neutron changes to a u quark by emitting a W boson;

Examiners report

[N/A]

50.

[6 marks]

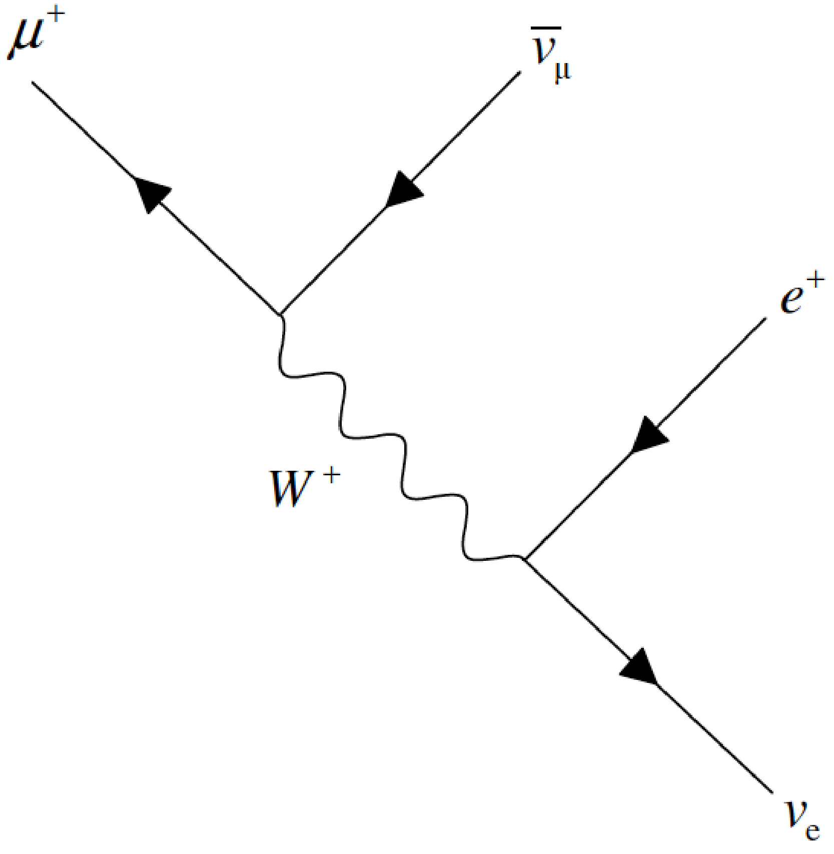
Markscheme

(i)

	μ^+	e^+	ν_e	$\overline{\nu}_\mu$
L	–1	–1	+1	–1;
L_e	0	–1	+1	0;
L_μ	–1	0	0	–1;

*Award **[1]** for each correct row.*

(ii)



W^+;
any other two correct;
and other two correct;

Examiners report

[N/A]

51. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

52. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

53a. *[4 marks]*

Markscheme

power produced $\left(\frac{24}{0.32}\right)$=75MW;
energy produced in a year (75×10^6×365×24×60×60=)2.37×10^{15}J;
number of reactions required in one year $\left(\frac{2.37\times10^{15}}{3.2\times10^{-11}}\right) = 7.39 \times 10^{25}$;
mass used (7.39×10^{25}×235×1.66×10^{-27})≈29kg;

or

mass used $\left(\frac{7.39\times10^{25}}{6.02\times10^{23}} \times 235 \times 10^{-3}\right) = 29\text{kg}$;

Examiners report

[N/A]

53b. *[3 marks]*

Markscheme

the neutrons would not be slowed down;
therefore they would not be/have less chance of being captured/induce fission;
so (much) less/no power would be produced;

Examiners report

[N/A]

53c. *[3 marks]*

Markscheme

(i) beta decay;

(ii) the reactions end up producing plutonium (from uranium 238);
(this isotope of) plutonium may be used to manufacture nuclear weapons / can be used as fuel in other reactors / plutonium is extremely toxic;

or

the products of the reactions are radioactive for long periods of time / *OWTTE*;
therefore posing storage/safety problems;

Examiners report

[N/A]

54a. *[6 marks]*

Markscheme

(i) the amplitude is constant;

(ii) period is 0.20s;

$a_{\max} = \left(\left[\frac{2\pi}{T}\right]^2 x_0 = 31.4^2 \times 2.0 \times 10^{-2}\right) = 19.7 \approx 20\text{ms}^{-2}$

*Award **[2]** for correct bald answer and ignore any negative signs in answer.*

(iii) displacement at t = 0.12cm is (−)1.62cm;
$v\left(= \frac{2\pi}{T}\sqrt{x_0 - x^2}\right) = 31.4\sqrt{\left(2.0 \times 10^{-2}\right)^2 - \left(1.62 \times 10^{-2}\right)^2} = 0.37\text{ms}^{-1}$;
Accept displacement in range 1.60 to 1.70 cm for an answer in range 0.33ms^{-1} to 0.38ms^{-1}.

or

$v_0 = \frac{2\pi}{T}x_0 = 0.628\text{ms}^{-1}$;
$|v| = \left(\left|-v_0 \sin\left[\frac{2\pi}{T}t\right]\right| \Rightarrow |v| = |-0.628\sin[31.4 \times 0.12]| = |0.37|\right) = 0.37\text{ms}^{-1}$;

or

drawing a tangent at 0.12s;
measurement of slope of tangent;
Accept answer in range 0.33ms^{-1} to 0.38ms^{-1} .

Examiners report

[N/A]

54b. *[4 marks]*

Markscheme

(i) use of $f = \frac{1}{T}$;
and so $f\left(= \frac{1}{0.20}\right) = 5.0\text{Hz}$;

(ii) wavelength is 16cm;
and so speed is $v(=f\lambda=5.0\times0.16)=0.80\text{ms}^{-1}$;

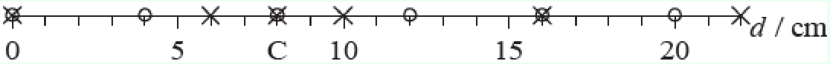
Examiners report

[N/A]

54c. *[4 marks]*

Markscheme

(i) points at 0, 8 and 16 cm stay in the same place;
points at 4 and 20 cm move 2 cm to the right;
point at 12 cm moves 2 cm to the left;



(ii) the point at 8 cm;

Examiners report

[N/A]

55a. *[4 marks]*

Markscheme

(i) the (minimum) energy required to completely separate the nucleons of a nucleus / the energy released when a nucleus is assembled;

(ii) mass defect is $94\times1.007276+145\times1.008665-238.990396=1.95\text{u}$;
binding energy is $1.95\times931.5=1816\text{MeV}$;
binding energy per nucleon is $\frac{1816}{239}$MeV;
$=7.6\text{MeV}$

Examiners report

[N/A]

55b. *[3 marks]*

Markscheme

(i) $x=3$;

(ii) binding energy of plutonium is $7.6\times239=1816\approx1800\text{MeV}$
(known in (ii))
binding energy of products is $8.6\times91+8.2\times146=1980\approx2000\text{MeV}$;
energy released is $(2000-1800)=200\text{MeV}$;

Examiners report

[N/A]

55c. *[4 marks]*

Markscheme

the electric force is repulsive/tends to split the nucleus;
the electric force acts on protons, the strong nuclear force acts on nucleons;
the nuclear force is attractive/binds the nucleons;
but the electric force is long range whereas the nuclear force is short range;
so adding more neutrons (compared to protons) contributes to binding and does not add to tendency to split the nucleus / a proton repels every other proton (in the nucleus) so extra neutrons are needed for binding;

Examiners report

[N/A]

56.

[1 mark]

Markscheme

A

Examiners report

[N/A]