1)

(a)	(i)	88 protons ✓ 140 neutrons ✓ 88 electrons ✓	**3**
(a)	(ii)	electron ✓	**1**
(a)	(iii)	$^{228}_{88}\text{Ra} \rightarrow {}^{228}_{89}\text{Ac} + {}^{0}_{-1}\text{e} + \bar{\nu}_e$ ✓✓✓✓	**4**
(b)		228 ± 10 ✓ 88 ✓	**2**
		Total	**10**

2)

a		the ratio of charge to mass of nucleus ✓ C kg^{-1} ✓	**2**
b	i	number of protons and neutrons the same **or** number of neutrons less **or** mass the same ✓ but more protons therefore greater charge ✓	**2**
b	ii	answers add up to 10 ✓ number of protons = 4 ✓ number of neutrons = 10 – 4 = 6 ✓ evidence of correct calculation ✓ eg 5q = 1.25 × ?q ? = 4	**4**
		Total	**8**

3)

a	(i)	neutron✓	1	accept symbols symbols e.g. n
a	(ii)	electron✓	1	accept symbols
a	(iii)	neutron✓	1	accept symbols
b	(i)	antineutrino✓	1	$\overline{\upsilon_{(e)}}$
b	(ii)	A=99✓ Z= 44 ✓	2	
b	(iii)	specific charge = 43 × 1.6 × 10^{-19} ✓/99×1.66×10^{-27} ✓ specific charge = 4.2 × 10^{7} ✓ C kg^{-1}✓	4	Correct answer no working -1 If include mass of electrons lose 2 and 3 mark

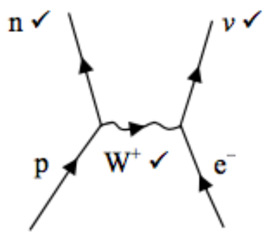
4)

<table>
<tr><td>(a)</td><td></td><td>isotopes (are varieties of the same element that) have the same number of protons/atomic number/proton number ✓
but different numbers of neutrons/nucleons/atomic mass ✓</td><td>2</td></tr>
<tr><td>(b)</td><td>(i)/
(ii)/
(iii)/
(iv)</td><td>
<table>
<tr><td></td><td>number of protons</td><td>number of neutrons</td><td>specific charge of nucleus/
C kg^{-1} ✓</td></tr>
<tr><td>first isotope</td><td>92</td><td>143</td><td>$=92 \times 1.6 \times 10^{-19}$ ✓
$/(92 \times 1.67 \times 10^{-27}$
$+143 \times 1.67 \times 10^{-27})$ ✓
$= 3.8 \times 10^{7}$ ✓</td></tr>
<tr><td>second isotope</td><td>92 ✓</td><td>$3.7 \times 10^{7} = 92 \times 1.6 \times 10^{-19}$
$/(A \times 1.67 \times 10^{-27})$ ✓
$A \times 1.67 \times 10^{-27} =$
$92 \times 1.6 \times 10^{-19}/3.7 \times 10^{7}$
A = 238 ✓
number of neutrons
= 238 - 92=146 ✓ **or**
148 if used u **or** 147
(depends on rounding)</td><td>3.7×10^{7}</td></tr>
</table>
</td><td>8</td></tr>
<tr><td></td><td></td><td>Total</td><td>10</td></tr>
</table>

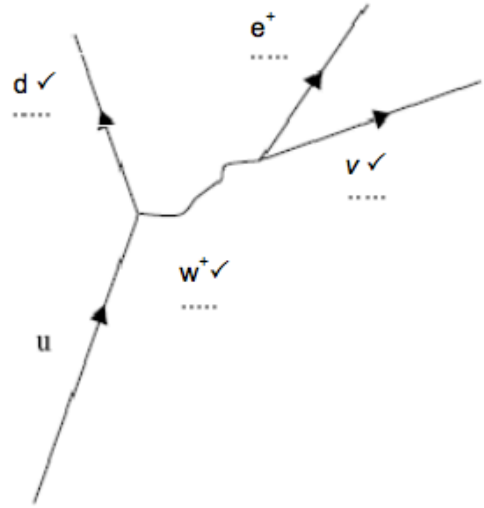
5)

(a)	(i)	an electron ✓	1
(a)	(ii)	change in *A* = 0 ✓ change in *Z* = +1 ✓	2
(b)	(i)	${}^{A}_{Z}X \rightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}e + \overline{\nu_e}$ ✓ **or** $n \rightarrow p + e^{-} + \overline{\nu_e}$ **or** $d \rightarrow u + e^{-} + \overline{\nu_e}$	1
(b)	(ii)	lepton number must be conserved ✓ lepton number before decay equals zero hence after decay lepton number of electrons cancels with lepton number of anti-neutrino **or** zero on both sides ✓	2
(b)	(iii)	hypothesis needs to be tested by experiment ✓ experiment must be repeatable ✓ **or** hypothesis rejected	2
		Total	8

6)

(a)	(i)	electromagnetic ✓ photon (or γ) ✓	
	(ii)	charge mass lepton number baryon number strangeness any two ✓✓	**4**
(b)	(i)		
	(ii)	weak ✓	
	(iii)	charge ✓ charge before = + and – = 0 same after ✓ baryon number ✓ +1 before (p) and +1 after (n) ✓ lepton number ✓ +1 before and +1 after ✓ **or** strangeness	**7**
	(iv)	if a reliable experiment does not support a hypothesis **or** experiment proves/disproves/checks theory ✓ the hypothesis must be changed/rejected **or** hypothesis/theory can be extended to other areas ✓	
		Total	**11**

7)

(a)	neutrino ✓	**1**
(b)	proton number = 10 ✓ nucleon number = 22 ✓	**2**
(c)	baryon = neutron ✓ lepton = positron ✓ lepton = neutrino ✓	**3**
(d)	ddu and uud ✓	**1**
(e)	 -1 for each error	**3**
	Total	**10**

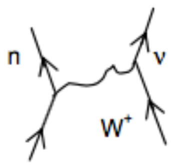
8)

(a)		repulsive then attractive ✓ short range (if distance quoted must be of order fm) ✓ correct distance for cross over (accept range 0.1 – 1.0 fm) ✓	**3**
(b)	(i)	a helium nucleus (accept 2p and 2n) ✓	**1**
(b)	(ii)	${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$ ✓	**2**
(c)	(i)	same atomic number/proton number ✓ different number of neutrons/nucleons ✓	**2**
(c)	(ii)	evidence of subtraction of mass number or atomic number ✓ (thus atomic number decreases to) **76** ✓ (atomic number of lead is 82 therefore) **6** (82 – 76) beta decays ✓	**3**
		Total	**11**

9)

i	same atomic number/number of protons ✓ different mass/nucleon number/different number of neutrons ✓	**2**
ii	${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$ ✓✓	**2**
iii	$\frac{q}{m} = \frac{2 \times 1.6 \times 10^{-19}}{4 \times 1.67 \times 10^{-27}}$ ✓✓ $\frac{q}{m} = 4.8 \times 10^{7}\ \mathrm{C\,kg^{-1}}$ ✓✓	**4**
iv	strong nuclear force is short range ✓ no effect at distances larger 3 fm (except any distance less than 10 fm) ✓	**2**
	Total	**10**

10)

a		${}^{40}_{19}\mathrm{K} \rightarrow {}^{40}_{18}\mathrm{Ar} + {}^{0}_{1}e + \nu_e$ ✓✓✓✓ (accept + for 1 and e^+ or β^+)	**4**
b	i	electron/K capture ✓	**1**
b	ii	(inner) shell (of atom) ✓	**1**
b	iii	conservation of **lepton number** ✓	**1**
b	iv	 *n* ✓ *v* ✓ W^+ ✓	**3**
		Total	**10**

11)

a	i	nucleon number is the number of protons and neutrons OR mass number proton number is the number of protons OR atomic number✓	1
a	ii	14 – 6 =8 ✓	1
a	iii	specific charge =$6 \times 1.6 \times 10^{-19}$✓/($14 \times 1.66 \times 10^{-27}$ ✓) specific charge = 4.1×10^{7} (C kg^{-1}) ✓	3
b	i	isotopes are variations of an element that have same proton/atomic number ✓ but different nucleon number OR different number of neutrons ✓	2
b	ii	$4.8 \times 10^{7} = 6 \times 1.6 \times 10^{-19}$ ✓/($A \times 1.66 \times 10^{-27}$) $A = 6 \times 1.6 \times 10^{-19}/(4.8 \times 10^{7} \times 1.66 \times 10^{-27})$ A = 12 ✓ Number of neutrons = 12-6 ✓	3

12)

(a)	(i)	protons = 20✓ neutrons = 28✓ electrons = 18✓	3	
(a)	(ii)	$2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19}$ ✓(C)	1	-ve sign loses mark
(a)	(iii)	specific charge = $3.2 \times 10^{-19}/(48 \times 1.67 \times 10^{-27} + 18 \times 9.11 \times 10^{-31})$ ✓ specific charge = 4.0×10^{6} C kg^{-1} ✓	2	Allow 1.66 Allow CE from (ii) First mark is for mass if miss out electron mass and do not justify lose first mark

13)

a	(i)	Q/boron/B✓	1		
a	(ii)	P and R/ R and P✓	1		
a	(iii)	R✓ 6/14 is smallest fraction/0.43 smallest ratio/4.13×10^{7} C/kg✓	2		Cannot get second mark if not awarded first mark

a	(iv)	${}^{14}_{6}R \rightarrow {}^{14}_{7}X + {}^{0}_{-1}e + \overline{\nu}_{(e)}$ ✓✓✓	3		one mark for each correct symbol on rhs ignore –ve sign on e. Can have neutrino with 0,0 on answer lines ignore any subscript on neutrino

b	(i)	repulsive below/at 0.5 fm (accept any value less or equal to 1 fm)✓ attractive up to/at 3 fm (accept any value between 0.5 and 10 fm)✓ short range OR becomes zero OR no effect✓	3		Can get marks from labelled graph Don't accept negligible for 3rd mark

b	(ii)	interaction: electromagnetic/em✓ (virtual) photon/ γ✓	2		

14)

a	(table below)	one mark for each correct row (ignore first row as already ticked) allow cross instead of tick and ignore any crossed out ticks if more than one tick in a row then no mark	4
bi	the atom has lost two electrons✓		1
bii	(*use of specific charge = charge ÷ mass*) mass = $3.2 \times 10^{-19} \div 8.57 \times 10^{5} = 3.734 \times 10^{-25}$ (kg) mass number = $3.734 \times 10^{-25} \div 1.66 \times 10^{-27}$ ✓(= 225) hence ${}^{225}_{(88)}$Ra OR 225✓✓ OR calculate specific charge for each isotope✓ hence ${}^{225}_{(88)}$Ra OR 225✓✓	ignore any reference to electrons first mark for deduction bald correct answer scores 2 marks don't need radium symbol or 88 wrong answer scores zero	3

Table for part a:

	${}^{223}_{88}$Ra	${}^{224}_{88}$Ra	${}^{225}_{88}$Ra	${}^{226}_{88}$Ra
Isotope with smallest mass number	(✓)			
Isotope with most neutrons in nucleus				✓
Isotope with nucleus that has highest specific charge	✓			
Isotope that decays by β^- decay to form ${}^{225}_{89}$Ac			✓	
Isotope that decays by alpha decay to form ${}^{220}_{86}$Rn		✓		