1 **(a)** **(i)** Complete Fig. 9.1 to show the quark composition and charge for neutrons and protons.

	quark composition	charge
neutron		
proton		

Fig. 9.1

[2]

(ii) Complete Fig. 9.2 to show the composition of quarks.

quark	charge	baryon number	strangeness
up		+ 1/	
down			0

Fig. 9.2

[2]

(b) When a neutron decays it can produce particles that include an electron.

(i) Complete the decay equation below for a neutron.

$^{1}_{0}n \rightarrow$

[2]

(ii) Name the interaction responsible for the decay of the neutron.

..... **[1]**

(iii) Electrons and neutrons belong to different groups of particles. Name the group of particles to which each belongs.

electrons .....

neutrons ..... **[1]**

[Total: 8]

2 **(a)** Describe what is meant by the **spontaneous** and **random** nature of radioactive decay of unstable nuclei.

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..... **[2]**

(b) Define the *decay constant*.

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..... **[2]**

(c) Explain the technique of radioactive carbon-dating.

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..... **[4]**

(d) The activity of a sample of living wood was measured over a period of time and averaged to give 0.249 Bq. The same mass of a sample of dead wood was measured in the same way and the activity was 0.194 Bq. The half-life of carbon-14 is 5570 years.

(i) Calculate

1 the decay constant in y^{-1} for the carbon-14 isotope

decay constant = ... y^{-1} **[1]**

2 the age of the sample of dead wood in years.

age = ... y **[2]**

(ii) Suggest why the activity was measured over a long time period and then averaged.

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..... **[1]**

(iii) Explain why the method of carbon-dating is not appropriate for samples that are greater than 10^5 years old.

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..... **[1]**

[Total: 13]

3 Technetium-99m is a common medical tracer injected into patients before they have a scan with a gamma camera. Technetium-99m is a gamma emitter with a half-life of about 6 hours. Each gamma ray photon has energy 2.2×10^{-14} J.

A patient is given a dose with an initial activity of 500 MBq.

(a) Explain what is meant by *activity*.

.....

..... **[1]**

(b) Calculate the initial rate of energy emission from the dose of technetium-99m.

rate of energy emission = ... $J\,s^{-1}$ **[2]**

(c) Name and describe the function of the main components of a gamma camera.

In your answer you should make clear how a good quality image can be achieved with these components.

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..... **[5]**

[Total: 8]

4 Fluorodeoxyglucose (FDG) is a radiopharmaceutical used for PET scans. It contains radioactive fluorine-18, which is a positron-emitter with a half-life of 6.6×10^3 s.
A patient is injected with FDG which has an initial activity of 250 MBq.

(a) Calculate the decay constant of fluorine-18.

decay constant = ... s^{-1} **[2]**

(b) Show that the initial number of fluorine-18 nuclei in the FDG is about 2×10^{12}.

[1]

(c) About 9.9% of the mass of FDG is fluorine-18. Use your answer in **(b)** to determine the initial mass of FDG given to the patient. The molar mass of fluorine-18 is 0.018 kg mol^{-1}.

mass = ... kg **[3]**

(d) A typical PET scan takes 20 minutes. Determine the activity of FDG in the patient after this time.

activity = ...MBq **[2]**

(e) Positron emission tomography (PET) can be used to locate an area of increased activity within the brain. Describe the principles of PET.

In your answer you should make clear how the position of increased activity is located.

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..... **[4]**

[Total: 12]