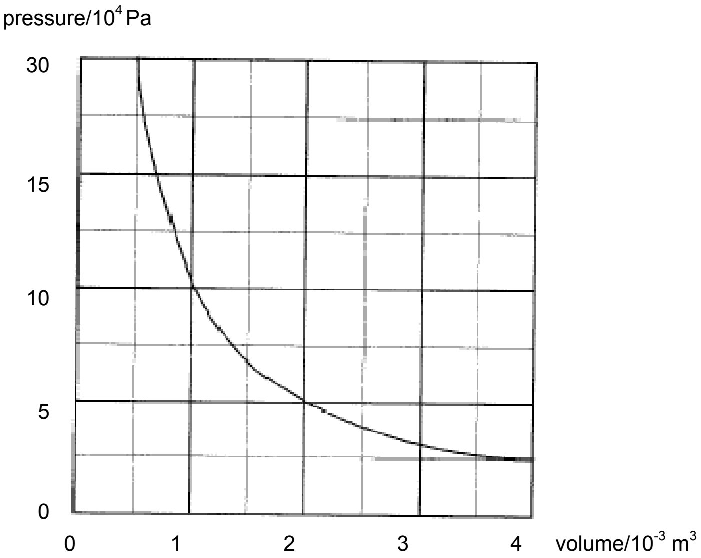
GCE Physics, Specification A, PHYA5/2A, Section A, Nuclear and Thermal Physics

Question 1		
(a)	using $Q = mc\Delta\theta$ $= 3.00 \times 440 \times (84-27)$ ✓ 7.5×10^4 (J) ✓	**2**
(b)	using $Q = ml$ $= 1.20 \times 2.5 \times 10^4$ $= 3.0 \times 10^4$ (J) ✓	**1**
(c)	(heat supplied by lead changing state + heat supplied by cooling lead = heat gained by iron) 3.0×10^4 + heat supplied by cooling lead = 7.5×10^4 ✓ heat supplied by cooling lead = $4.5 \times 10^4 = mc\Delta\theta$ $c = 4.5 \times 10^4/(1.2 \times (327 - 84)$ ✓ $c = 154$ (J kg^{-1} K^{-1}) ✓	**3**
(d)	any **one** idea ✓ no allowance has been made for heat loss to the surroundings or the specific heats may not be a constant over the range of temperatures calculated	**1**
	Total	**7**

Question 2		
(a)	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate can explain the role of the moderator and control rods in maintaining a critical condition inside the reactor. The explanation is given in a clear sequence of events and the critical condition is defined in terms of neutrons. To obtain the top mark some other detail must be included. Such as, one of the alternative scattering or absorbing possibilities or appropriate reference to critical mass or detailed description of the feedback to adjust the position of the control rods etc. **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate has a clear idea of two of the following: the role of the moderator, the role of the control rods or can explain the critical condition. **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate explains that a released neutron is absorbed by uranium to cause a further fission. Alternatively the candidate may explain one of the following: the role of the moderator, the role of the control rods or can explain the critical condition. **The explanation expected could include the following events that could happen to a released neutron.** a neutron is slowed by the moderator taking about 50 collisions to reach thermal speeds then absorbed by uranium-235 to cause a fission event one neutron released goes on to cause a further fission is the critical condition a neutron may leave the reactor core without further interaction a neutron could be absorbed by uranium-238 a neutron could be absorbed by a control rod a neutron could be scattered by uranium-238 a neutron could be scattered by uranium-235	**max 6**

(b)	it is easy to stay out of range or easy to contain an α source or β/γ have greater range/are more difficult to screen ✓ most (fission fragments) are (more) radioactive/unstable ✓ and are initially most likely to be beta emitters/(which also) emit γ radiation/are neutron **rich**/**heavy** ✓ **ionising** radiation damages body tissue/is harmful ✓	**max 3**
	Total	**9**

Question 3		
(a)	probability of decay per unit time/given time period **or** fraction of atoms decaying per second **or** the rate of radioactive decay is proportional to the number of (unstable) nuclei and nuclear decay constant is the constant of proportionality ✓	**1**
(b)	use of $T_{\frac{1}{2}} = \frac{ln2}{\lambda}$ $T_{\frac{1}{2}}$ = ln2/3.84 × 10^{-12} s ✓ (1.805 × 10^{11} s) = (1.805 × 10^{11}/3.15 × 10^{7}) = 5730 y ✓ answer given to 3 sf ✓	**3**
(c)	number of nuclei = N = 3.00 × 10^{23} × 1/10^{12} ✓ (= 3.00 × 10^{11} nuclei) (using $\frac{\Delta N}{\Delta t} = -\lambda N$) rate of decay = 3.84 × 10^{-12} × 3.00 × 10^{11} ✓ (= 1.15 Bq)	**2**
(d)	($N = N_0e^{-\lambda t}$ and activity is proportional to the number of nuclei $A \propto N$ use of $A = A_0e^{-\lambda t}$) 0.65 = 1.15 × $e^{-3.84 \times 10^{-12} t}$ ✓ $t = \frac{ln\left(\frac{1.15}{0.65}\right)}{3.84 \times 10^{-12}}$ or $\frac{ln\left(\frac{0.651}{1.15}\right)}{-3.84 \times 10^{-12}}$ ✓ t = 4720 y ✓	**3**
(e)	the boat may have been made with the wood some time after the tree was cut down the background activity is high compared to the observed count rates the count rates are low or sample size/mass is small or there is statistical variation in the recorded results possible contamination uncertainty in the ratio of carbon-14 in carbon thousands of years ago any two ✓✓	**2**
	Total	**11**

<table>
<tr><th>Question 4</th><th></th><th></th></tr>
<tr><td>(a)</td><td>


curve with decreasing negative gradient that passes through the given point which does not touch the x axis ✓

<table>
<tr><th colspan="2">designated points</th></tr>
<tr><th>pressure/10^4 Pa</th><th>volume/10^{-3} m^3</th></tr>
<tr><td>10</td><td>1.0</td></tr>
<tr><td>5.0</td><td>2.0</td></tr>
<tr><td>4.0</td><td>2.5</td></tr>
<tr><td>2.5</td><td>4.0</td></tr>
</table>

2 of the designated points ✓✓ (one mark each)</td><td>3</td></tr>
<tr><td>(b) (i)</td><td>$N = PV/kT = 5 \times 10^4 \times 2 \times 10^{-3}/1.38 \times 10^{-23} \times 290$ ✓

[or alternative use of $PV = nRT$
$5 \times 10^4 \times 2.0 \times 10^{-3}/8.31 \times 290 = 0.0415$ moles]
$= 2.50 \times 10^{22}$ molecules ✓</td><td>2</td></tr>
<tr><td>(b) (ii)</td><td>(mean) kinetic energy of a molecule = $\frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ ✓

(= 6.00×10^{-21} J)

(total kinetic energy = mean kinetic energy × N)
$= 6.00 \times 10^{-21} \times 2.50 \times 10^{22}$ ✓

= 150 (J) ✓</td><td>3</td></tr>
</table>

(c)	all molecules/atoms are identical molecules/atoms are in random motion Newtonian mechanics apply gas contains a large number of molecules the volume of gas molecules is negligible (compared to the volume occupied by the gas) or reference to point masses no force act between molecules except during collisions or the speed/velocity is constant between collisions or motion is in a straight line between collisions collisions are elastic or **kinetic** energy is conserved and of negligible duration any 4 ✓✓✓✓	**max 4**
	Total	**12**