2018 MJC H2 Physics Prelim Exam Paper 3
Suggested solutions

1 (a) (i)

Newton's first law of motion states that a body continues at rest or at constant / uniform velocity unless acted on by a <u>resultant</u> (external) force. [A1]

Comments:
1. many students wrote uniform motion or constant speed instead of uniform velocity (and this is penalised)
2. many students did not indicate "resultant"

(ii)

resultant force (in any direction) is zero [B1]
resultant moment / torque (about any axis) is zero [B1]

Comments:
1. very well done

(b)

(i)

Using principle of moment and taking moment about the bottom of ladder: [B1]
clockwise moment = anticlockwise moment

$N \times L \sin 60° = W \times \frac{L}{2} \cos 60°$

$N \times L \sin 60° = 80 \times \frac{L}{2} \cos 60°$ [B1]

N = 23 N [A0]

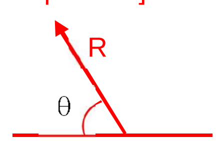
Comments:
1. poorly done, a number of students either left blank or tried to balance the forces (which they would not be able to get the answer)
2. many students did not indicate using principle of moment (or sum of clockwise moment = sum of anticlockwise moment) nor indicate which point to take moment about

(ii)

Resolve vertically: $\uparrow$ Y = W = 80 N
Resolve horizontally $\leftarrow$ X = N = 23 N [C1 for both equations]

force R = $\sqrt{X^2 + Y^2} = \sqrt{23^2 + 80^2}$ = 83 N [A1]

angle $\theta = \tan^{-1}\left(\frac{Y}{X}\right) = \tan^{-1}\left(\frac{80}{23}\right)$ = 74°



Direction: 74° clockwise above horizontal [A1]

OR
by vector triangle [C1]
get R [A1]
get angle θ [A1]

Comments:
1. generally able to get answer although in some cases the direction is not written clearly (a diagram showing the direction of R would help)

(iii)

1.

(Due to the person's weight) there is now greater downward force on the ladder, and so (to maintain equilibrium) the floor exerts a larger upward vertical force on the ladder. [A1]

Comments:
1. some students used Newton's third law or action and reaction

2.

(Due to the person's weight) there is now a greater anticlockwise moment about the ladder bottom, and so (to maintain equilibrium) the wall exerts a greater clockwise moment and hence greater horizontal force. [A1]

Comments:
1. many students thought the horizontal force remained unchanged because no horizontal component of force is exerted by the person

2

(a)

uncertainty in $\theta = \dfrac{10.5 - 9.7}{2} = 0.4$ K

Accept:

average $\theta = \dfrac{10.2 + 9.7 + 10.5}{3} = 10.133$ K

uncertainty in $\theta = 10.13 - 9.7 = 0.433 = 0.4$ K

Comments:
1. Not well done. Many students stated 0.1 K, 0.2 K, 0.5 K etc, making no reference to the data given. Some students presented the uncertainty to 2 or 3 s.f.

(b)

$$c = \frac{Q}{m\theta} \quad = \frac{IVt}{m\theta}$$

$$= \frac{4.125 \times 11.8 \times 200.0}{0.309 \times 10.133} \qquad \text{[C1]}$$

$$= 3110 \text{ J kg}^{-1} \text{ K}^{-1} \qquad \text{[A1]}$$

Comments:
Common mistakes include:

1. applying wrong equations. It was common to see students equating $Q = It$ (amount of charge = current × time) with Q (heat) = $mc\Delta\theta$. Students must be aware of what the symbols in the equations represent.
2. not converting 309 g to kg
3. not calculating the mean temperature of all 3 sets of data

(c)

$$\frac{\Delta c}{c} = \frac{\Delta V}{V} + \frac{\Delta I}{I} + \frac{\Delta t}{t} + \frac{\Delta m}{m} + \frac{\Delta(\theta)}{\theta}$$

$$= \frac{0.3}{11.8} + \frac{0.002}{4.125} + \frac{0.5}{200.0} + \frac{3}{309} + \frac{0.4}{10.1} \qquad \text{[M1]}$$

$$= 0.077721$$

$$\Delta c = 3110 \times 0.077721 = 241.7$$

$$= 200 \text{ (1 s.f.)} \qquad \text{[M1]}$$

$$c = 3100 \pm 200 \text{ J kg}^{-1} \text{ K}^{-1} \qquad \text{[A1]}$$

Alternative:

$$c_{max} = \frac{I_{max} V_{max} t_{max}}{m_{min} \theta_{min}}$$

$$= \frac{4.127 \times 12.1 \times 200.5}{0.306 \times 9.7}$$

$$= 3373$$

$$\Delta c = 3373 - 3110 \qquad \text{[M1]}$$

$$= 263$$

$$= 300 \text{ (1. s.f.)} \qquad \text{[M1]}$$

$$c = 3100 \pm 300 \text{ J kg}^{-1} \text{ K}^{-1} \qquad \text{[A1]}$$

Comments:

1. Not well done. Students who used the equation $Q = It$ get zero credit for this part too.

2. Vast majority of the cohort did not present the absolute uncertainty to 1 s.f., and/or did not present *c* to the same order of precision as Δc.
3. Some students did not make c the subject before applying the equation for fractional uncertainty.

(d)

No heat loss to surrounding.
or All electrical energy is converted to heat. [B1]
Comments:
1. Very well done.
2. No credit was given for students who stated that I and V are constant values, since these are values stated in the question.

3 (a)

Newton's second law of motion states that the rate of change of momentum is proportional to the net / resultant (external) force (acting on it)
and the change (of momentum) takes place in the direction of the (net) force [A1]

Comments:
1. a number of students mentioned acceleration instead of momentum

(b)

(i)

$$s = ut + \frac{1}{2}at^2 = (20)(12) + \frac{1}{2}\frac{4800}{800}(12)^2 \qquad \text{[C1]}$$
$$= 672 \text{ m} \qquad \text{[A1]}$$

Comments:
1. very well done

(ii)

$$v = u + at = 20 + \frac{4800}{800}(12) \qquad \text{[C1]}$$
$$= 92 \text{ m s}^{-1} \qquad \text{[A1]}$$

Comments:
1. very well done

(iii)

1.

$$\text{work} = Fs = (4800)(672) \qquad \text{[M0]}$$
$$= 3.23 \times 10^6 \text{ J} \qquad \text{[A1]}$$

Comments:

1. very well done

2.

work = gain in KE

$$= \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \frac{1}{2}(800)(92)^2 - \frac{1}{2}(800)(20)^2 \quad [M0]$$

$$= 3.23 \times 10^6 \text{ J} \quad [A1]$$

Comments:

1. a number of students did not minus the initial KE

(iv)

impulse = change in momentum

= $mv - mu$ = (800)(92) – (800)(20) [C1]

= 5.76×10^4 N s [A1]

OR use impulse = Ft = (4800)(12) = 5.76×10^4 N s

Comments:

1. very well done

4

(a)

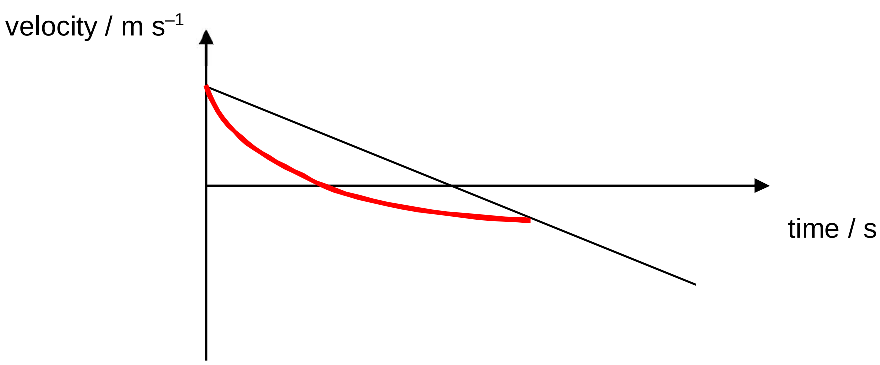


Fig. 4.1

curve from +15 m s^{-1} steepest at first then gentler and gentler [B1]
gradient at v = 0 should be same as that of original line. [B1 provided correct graph shape]
areas under graph above and below x-axis are similar (when the curve hits the straight line). [B1 provided correct graph shape]

Comments:

1. poorly done, most students could not get the last two marks

(b)

greater resultant (downward opposing) force, so lesser height [A1]

Comments:

1. many students wrongly stated there is less net force; many thought that there is a net upward force when object is moving up and air resistance reduced the net upward force

5

(a)

No resultant (external) force (acts on the system) so (by principle of conservation of momentum) the total momentum is conserved. [A1]

Comments:

1. a number of students say not conserved because collision is inelastic

(b)

conservation of momentum: $\rightarrow$ (0.800)(9.2) + 0 = (3.200) V $\Rightarrow$ V = 2.3 m s^{-1} [C1]

initial kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}(0.800)(9.2)^2 = 33.856$ J

final kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}(3.200)(2.3)^2 = 8.464$ J

% loss in kinetic energy = $\frac{33.856 - 8.464}{33.856} \times 100\% = 75\%$ [A1]

Comments:

1. some students equate final speed and KE as zero

(c)

conservation of energy: $\frac{1}{2}m_{\text{A\&B}}v^2 = \frac{1}{2}kx^2$

$\frac{1}{2}(3.2)(2.3)^2 = \frac{1}{2}(2500)x^2$ [M1]

$x = 0.082$ m [A1]

Comments:

1. a number of students only use the mass of ball B

6

(a)

Straight lines in uniform radial pattern centred on charge [B1]
Arrows pointing inwards [B1]

Comments:
1. Many students did not label the field lines. BOD was given
2. This part was very well done. Mistakes include: uneven separation of *E* field lines or wrong direction of arrows.

(b)

Electric field points inwards, because *E* points from points of higher potential to lower potential.
OR potential is negative suggests that the sphere is negatively charged and hence electric field points inwards. [B1]

Electric field is numerically equal to the potential gradient and is stronger where the potential gradient is stronger (closer to the charged sphere). The stronger E field is shown by the closer spacing between the E field lines. [B1]

Comments:
1. This part was very poorly done. Most students stated that *E* is proportional to *V*, making no reference to potential gradient.
2. It was also common to see answers that made no reference to the drawing in **(a)**.

(c) (i)

If V is inversely proportional to x, then Vx = constant [B1]
Multiplying **any 2** values [B1] to conclude that Vx is constant:

x / m	V / V	Vx / V m
0.19	-1.50×10^5	-28.5×10^3
0.25	-1.14×10^5	-28.5×10^3
0.32	-0.89×10^5	-28.48×10^3 $= -28.5 \times 10^3$
0.39	-0.73×10^5	-28.47×10^3 $= -28.5 \times 10^3$

Comments:
1. Generally well done.
2. Students are reminded to present their workings clearly for a “show” type of question. Some students lost marks due to unclear workings.
3. Some students stated that |*V*| increases when *x* decrease without working out the proportionality constant.

(ii)

Using value of $Vx = -28.5 \times 10^3$ V m [M1]
R = $-28.5 \times 10^3 / -1.9 \times 10^5 = 0.15$ m [A1]

(iii)

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

$$Q = 4\pi\varepsilon_0 rV$$

$$= 4\pi\left(8.85\times10^{-12}\right)(0.15)\left(-1.9\times10^{5}\right) \qquad [C1]$$

$$= -3.17\times10^{-6}\,\text{C}$$

$$= -3.2\times10^{-6}\,\text{C} \;[A1]$$

Comments:

1. Parts (ii) and (iii) were very well done. Most students scored full credit. Common mistakes include power of tens error, or missing out the negative sign for the charge.

7 (a)

(i)

The power bank converts 12.0 J of electrical energy from chemical energy (or other forms) [B1]
when one coulomb of charge passes through it. [B1]

Comments:
Very badly done. Most candidates did not understand the idea of e.m.f. and what 12.0 V means.
Common mistakes:

- … converts 12.0 V of electrical energy…
- … gains 12.0 J of electrical energy (without elaborating on the conversion of energy) …
- … per unit charge…
- … when one coulomb of charge moves around the circuit…

(ii)

Lamps A, B and C will be turned on with equal brightness [B1]

Comments:
Most could recognise that lamps A, B and C will be turned on, but few elaborated that the brightness will be equal.

(iii)

Note that all the lamps and devices are parallel to each other.
Total effective resistance

$$= 3.0 + \left(\frac{1}{25.0} + \frac{1}{25.0} + \frac{1}{25.0} + \frac{1}{25.0} + \frac{1}{25.0} + \frac{1}{38.0} + \frac{1}{42.0}\right)^{-1} \quad \text{[C1]}$$

$$= 6.998\ \Omega$$

$$I = \frac{V}{R} = \frac{12.0}{6.998} = 1.71\ \text{A} \quad \text{[A1]}$$

Comments:
Not very well done, considering that the circuit is not complicated.
Most candidates could somehow see that all the components (lamps and devices) are arranged in parallel, but may have mis-calculated the effective resistance.
A very common mistake was to simply take the e.m.f. of 12.0 V divided by the effective resistance, without taking into account the internal resistance of 3.0 Ω.

(iv)

$$V_{\text{terminal}} = E - Ir$$

$$= 12.0 - (1.71)(3.0) \quad \text{[C1]}$$

$$= 6.86\ \text{V} \quad \text{[A1]}$$

Comments:
Not very well done, considering that it is a simple follow-up from the previous part. Note that no e.c.f. is given if the final value of the terminal p.d. is more than 12.0 V.
Common mistakes:

- Used $V = E + Ir$
- Used $V = IR$, but used the internal resistance instead

(v)

Effective resistance across the lamps increase, hence p.d. across lamps increase (by potential divider principle). [M1]

Since $P = \frac{V^2}{R}$, power dissipated by lamps increase, hence brightness increase. [A1]

Comments:
Very poorly attempted. Many candidates could not see the effect of the internal resistance.
Common mistakes:

- Using the term "effective resistance of the circuit". Many meant only the effective resistance across the lamps.
- … effective resistance increase (vague), current decrease, hence brightness of lamps decrease… (note that this is actually not true. Current through the lamps actually increase!)
- … since S_4 and S_5 are now opened, all the current now flows into the lamps, hence brightness increase…

- … more current flows through the lamps… (without elaborating why)
- P.d. across the lamps remain the same since they are in parallel to the devices…
- … effective resistance decrease… (not correct)
- Wrong use of language – “more p.d. flows though the lamps”

(b)

(i)

$$V_{XY} = \frac{7.2}{7.2+2.0}(18.0) = 14.087 \text{ V} \quad \text{[C1]}$$

$$V_{\text{power bank}} = \frac{25.0}{25.0+3.0}(12.0) = 10.714 \text{ V} \quad \text{[M1]}$$

$$V_{\text{power bank}} = \frac{L}{L_{XY}} V_{XY}$$

$$10.714 = \frac{L}{1.00}(14.087)$$

$$L = 0.761 \text{ m} \quad \text{[A1]}$$

Comments:
A good number of candidates managed to get this correct. A very common mistake is to take 12/18.

(ii)

To reduce percentage or fractional uncertainty of balance length [B1]

Comments:
Poorly attempted.

(iii)

XY will have higher resistance, thus higher p.d. across XY by potential divider principle. [M1]
Thus a smaller balance length is needed to balance p.d. across the power bank. [A1]

Comments:
Candidates need to draw the links in their answers. Do not assume that the examiner will draw the link for you or give any benefit of doubt. Some candidates simply explained that the higher resistance will lead to shorter balance length without referring to the p.d. across XY. Other explained that the higher p.d. across XY will lead to shorter balance length without explaining that the higher p.d. is due to XY having a higher resistance.
There were also a handful who tried to explain using “balancing of resistance”. That is not the fundamental idea of how a potentiometer works.

Section B

8 (a) (i)

1.

$$\frac{GM_1M_2}{(R_1+R_2)^2}$$

Comments:

1. Very well done. Some forgot the square (power 2)

2.

$$M_1R_1\omega^2$$

Comments:

1. Very well done. Similarly, some forgot the power of 2.

(ii)

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{1.26\times10^8} = 5.0\times10^{-8}$$

Comments:

1. Very well done.

(iii)

By Newton's 3rd law, gravitational force on each of the stars is the same, [M1]

$F = ma_c$

$$\frac{GM_1M_2}{(R_1+R_2)^2} = M_1R_1\omega^2$$

$$\frac{GM_1M_2}{(R_1+R_2)^2} = M_2R_2\omega^2$$

Since angular velocity is the same,

$M_1R_1 = M_2R_2$

Hence $\frac{M_1}{M_2} = \frac{R_2}{R_1}$ [A0]

Comments:

1. Students did not "show" their reasoning clearly. The key idea is N3L where the gravitational force on each of the stars is the same.
2. Most students stated that centripetal force is the same without explaining the reason in comment (1).

[1]

(iv)

$R_1 = 0.80 \times 10^{11}$ m
$R_2 = 2.4 \times 10^{11}$ m

Comments:
1. Very well done. Except for some careless mistakes!!!

(v)

$$\frac{GM_1M_2}{(R_1+R_2)^2} = M_1R_1\omega^2 \qquad [\text{C1}]$$

$$M_2 = \frac{R_1\omega^2(R_1+R_2)^2}{G}$$

$$= \frac{(0.80\times10^{11})(5.0\times10^{-8})^2(3.2\times10^{11})^2}{6.67\times10^{-11}} \qquad [\text{M1}]$$

$$= 3.1\times10^{29} \qquad [\text{A1}]$$

Comments:
1. No E.C.F. for wrong Physics equations.
2. Most mistakes are due to carelessly missing out power of 2.

(b)

(i)

Force on electron = qE = $(1.6\times10^{-19})(4000) = 6.4\times10^{-16}$ N
Acceleration of electron $a_y = F / m = (6.4\times10^{-16}) / (9.11\times10^{-31})$ [M1]
$= 7.025\times10^{14}$ m s^{-2} [A0]

Comments:Very well done.

(ii)

Time taken = length / horizontal speed = $(5.1\times10^{-2}) / 1.7\times10^{7} = 3.0\times10^{-9}$ s [C1]
Final vertical component of velocity $v_y = u_y + a_y t = 0 + (7.025\times10^{14})(3.0\times10^{-9}) = 2.1\times10^{6}$ m s^{-1} [C1]
Final velocity =

$$\sqrt{v_x^2+v_y^2} = \sqrt{(1.7\times10^7)^2+(2.1\times10^6)^2} = 1.713\times10^7 \text{ m s}^{-1}$$

[A1]

$$\theta = \tan^{-1}\left(\frac{2.1\times10^6}{1.7\times10^7}\right) = 7.04° \qquad [\text{A1}]$$

Comments:
1. Many students are still mixing values in x and y directions into the same equation. E.g. s_x and a_y into the same equation.

(iii)

Deflection in opposite direction [A0] due to opposite (positive) sign of charge [M1]
Path is less curved [A0] because proton is less strongly deflected. Proton has same magnitude of charge as electron, experiences same magnitude of electric force, but proton has much larger mass -> acceleration is much smaller [M1]

Comments:

1. Most students did not specify the charge on the proton.
2. Most students did not make clear relation of larger mass lead to smaller acceleration.

(c)

(i)

Path in B-field is circular, Path in E-field is parabolic. [B1]
Circular – because magnetic force is (constant in magnitude and) always perpendicular to the velocity, so provides constant centripetal force toward a centre, causing uniform circular motion [B1]
Parabolic – because electric force is constant (in magnitude and direction) and in only one direction (perpendicular to the initial velocity), so acceleration in one direction and constant velocity in perpendicular direction. [B1]

Comments:

1. Most students stated “centripetal force pointing towards centre”, note that we should explain how the magnetic force is orientated to the electron motion instead.
2. Many use the word “upwards” vaguely in the description for electric force. Upwards may not be vertical upwards.

(ii)

Because centripetal force acts perpendicularly to the electron motion, the work done by the force is 0 (magnetic force only changes direction and not magnitude of velocity) [M1]
(Electron is in uniform circular motion),
Final speed of electron is the same as initial speed [A1]

Comments:

1. Most students only state that speed is constant in circular motion but did not explain why. No tangential acceleration or no work done by magnetic force should be stated.
2. Note that circular motion does not always means that speed is constant! There are non-uniform circular motion!

9

(a)

Radioactive decay not affected by external stimuli / conditions [B1]

Comments:

1. Well done.

(b) (i)

Total mass of products = 218.0090 + 4.0026 = 222.0116 u
Total mass of reactant = 222.0176 u
Difference in total mass = 0.0060 u [M1]
Conversion from u to kg = 00060 × 1.66 × 10^{27} = 9.96 × 10^{30} kg
Energy liberated = mc^2 = (9.96 × 10^{30})× (3.0 × $10^8)^2$ = [C1]
= 8.96 × 10^{-13} J [A1]

Comments:

1. Well done. But some students mistakenly calculated for mass defect / mass-energy of just products (did not subtract the mass of initial reactants)

(ii)

Since total momentum is conserved, and initial momentum of Rn-222 was zero,
The total momentum of the decay products must add up to zero. [M1]
The Po-218 and alpha particle move in opposite directions with equal (magnitude of) momentum. [B1]

Comments:

1. Most students did not answer to the requirements of the question "conservation of momentum".
2. Must explain in terms of momentum of the products.

(iii)

Since the mass of alpha particle / mass of Po-218 = 4 / 218
The speed of alpha particle / speed of Po-218 = 218 / 4
OR

$$m_\alpha v_\alpha = -m_{Po} v_{Po}$$

$$\frac{v_\alpha}{v_{Po}} = -\frac{m_{Po}}{m_\alpha}$$

[B1]

Hence the kinetic energy of alpha particle / kinetic energy of Po-218

$$\frac{\frac{1}{2} m_\alpha v_\alpha^2}{\frac{1}{2} m_{Po} v_{Po}^2} = \left(\frac{4}{218}\right)\left(\frac{218}{4}\right)^2 = 54.5 \qquad \text{[A0]}$$

(Using exact values given, 54.47)

Comments:

1. Poorly attempted. Many did not show clearly how to use conservation of momentum to find the ratio of the speeds of the products.

(c) (i)

	Number of neutrons	Number of protons	Mass of constituent nucleons in u	Mass defect in u	$\frac{\text{mass defect}}{\text{number of nucleons}}$
$^{222}_{86}Rn$	222-86 = 136	86	(86×1.00727) + (136×1.00866) = 223.80298	223.80298 – 222.0176 = 1.78538	1.78538 / 222 = 8.04225×10^{-3}

Number of

[C1 for correct number of neutrons and protons for both Rn-222 or Po-218]

[C1 for correct substitution / value for mass defect for Rn-222 and Po-218]

[A1 for correct final answers]

Comments:

1. Mass defect is the loss in mass when a nucleus is formed from its constituent nucleons!
2. Many students mistakenly mixed up mass defect as loss of mass in the reaction in **(b)**.

(ii)

Since mass defect is directly proportional to binding energy, a higher value of mass defect per nucleon means a higher binding energy <u>per nucleon</u>. [B1]

On average, it requires higher energy to break apart Po-218 into its constituent nucleons, compared to Rn-222. [M1]

Hence, Po-218 is more stable. [A1]

Comments:

1. Most students did not link mass defect per nucleon to binding energy per nucleon.
2. Many students did not explain what binding energy means (this is required to show that more energy is required to break Po-218 into constituents) so that it can be linked to stability.

(d)

(i)

It is the time taken for half the <u>original number of radioactive nuclei</u> to <u>decay</u>. [B1]

Comments:

1. Well done but some students were not clear on "number of nuclei".
2. Do not use definition for half-life from chemistry. Clearly not targeted at radioactive decay.

(ii)

Decay constant = ln2 / $t_{1/2}$ = ln 2 / (3.82 x 24 x 60 x 60)
= $2.11 \times 10^{-6}\ s^{-1}$

Comments:

1. Well done.

(iii)

Not valid [A0] as activity also depends on amount of radioactive material present [M1], and not just the half-life. ($A = \lambda N$)

Comments:

1. Badly done. Most students did not realise that it depends on *N*.
2. Some state "assuming *N* is constant" but note that the question says "**always**" have a high activity".

(e)

The observation suggests that Po-218 is unstable [B1]

The additional alpha particles detected come from the decay of Po-218 (and its daughter nuclides). [B1]

The almost-immediate decay of Po-218 (and its daughter nuclides) after it is produced shows that Po-218 has a very short half-life (half-lives), i.e. further alpha decays [B1]

Comments:

1. Most student did not mention about the short half-life that leads to significant higher number of alpha particle. (if half-life is long, activity will be relatively low and rate of emission of alpha particle will be low).
2. Some students seem to be using chemical equilibrium concepts to explain that the equilibrium point will be shifted right to produce more α particles. Note that nuclear reactions are Physical reactions involving changing of elements.