Hong Kong Diploma of Secondary Education Examination

Physics – Compulsory part (必修部分)

Section A – Heat and Gases (熱和氣體)
1. Temperature, Heat and Internal energy (溫度、熱和內能)
2. Transfer Processes (熱轉移過程)
3. Change of State (形態的改變)
4. General Gas Law (普適氣體定律)
5. Kinetic Theory (分子運動論)

Section B – Force and Motion (力和運動)
1. Position and Movement (位置和移動)
2. Newton's Laws (牛頓定律)
3. Moment of Force (力矩)
4. Work, Energy and Power (作功、能量和功率)
5. Momentum (動量)
6. Projectile Motion (拋體運動)
7. Circular Motion (圓周運動)
8. Gravitation (引力)

Section C – Wave Motion (波動)
1. Wave Propagation (波的推進)
2. Wave Phenomena (波動現象)
3. Reflection and Refraction of Light (光的反射及折射)
4. Lenses (透鏡)
5. Wave Nature of Light (光的波動特性)
6. Sound (聲音)

Section D – Electricity and Magnetism (電和磁)
1. Electrostatics (靜電學)
2. Electric Circuits (電路)
3. Domestic Electricity (家居用電)
4. Magnetic Field (磁場)
5. Electromagnetic Induction (電磁感應)
6. Alternating Current (交流電)

Section E – Radioactivity and Nuclear Energy (放射現象和核能)
1. Radiation and Radioactivity (輻射和放射現象)
2. Atomic Model (原子模型)
3. Nuclear Energy (核能)

Physics – Elective part (選修部分)

Elective 1 – Astronomy and Space Science (天文學和航天科學)
1. The universe seen in different scales (不同空間標度下的宇宙面貌)
2. Astronomy through history (天文學的發展史)
3. Orbital motions under gravity (重力下的軌道運動)
4. Stars and the universe (恒星和宇宙)

Elective 2 – Atomic World (原子世界)
1. Rutherford's atomic model (盧瑟福原子模型)
2. Photoelectric effect (光電效應)
3. Bohr's atomic model of hydrogen (玻爾的氫原子模型)
4. Particles or waves (粒子或波)
5. Probing into nano scale (窺探納米世界)

Elective 3 – Energy and Use of Energy (能量和能源的使用)
1. Electricity at home (家居用電)
2. Energy efficiency in building (建築的能源效率)
3. Energy efficiency in transportation (運輸業的能源效率)
4. Non-renewable energy sources (不可再生能源)
5. Renewable energy sources (可再生能源)

Elective 4 – Medical Physics (醫學物理學)
1. Making sense of the eye (眼的感官)
2. Making sense of the ear (耳的感官)
3. Medical imaging using non-ionizing radiation (非電離輻射醫學影像學)
4. Medical imaging using ionizing radiation (電離輻射醫學影像學)

RA3 : Nuclear Energy

Use the following data wherever necessary :

Atomic mass unit	$u = 1.661 \times 10^{-27}$ kg	(1 u is equivalent to 931 MeV)
Speed of light in vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}	
Charge of electron	$e = 1.6 \times 10^{-19}$ C	
Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}	
Molar gas constant	$R = 8.31$ J mol^{-1} K^{-1}	

The following list of formulae may be found useful :

Law of radioactive decay	$N = N_0 e^{-kt}$
Half-life and decay constant	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$
Activity and the number of undecayed nuclei	$A = kN$
Mass-energy relationship	$\Delta E = \Delta m c^2$

Part A : HKCE examination questions

1. **< HKCE 1983 Paper II - 37 >**

In the following nuclear reaction :

$$^{27}_{13}\text{Al} + ^{4}_{2}\text{He} \rightarrow ^{30}_{15}\text{P} + X$$

what is the mass number and atomic number of X ?

	Mass number	Atomic number
A.	1	0
B.	0	−1
C.	4	2
D.	0	0

2. **< HKCE 1986 Paper II - 40 >**

Which of the following equations represent(s) possible nuclear reactions ?

(1) $^{10}_{5}\text{B}$ + neutron $\longrightarrow$ $^{6}_{3}\text{Li}$ + α particle

(2) $^{210}_{83}\text{Bi}$ $\longrightarrow$ $^{210}_{84}\text{Po}$ + β particle

(3) $^{14}_{7}\text{N}$ + α particle $\longrightarrow$ $^{17}_{8}\text{O}$ + proton

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

3. **< HKCE 1991 Paper II - 39 >**

Which of the following equations represents(s) possible nuclear reaction(s) ?

(1) ${}^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \longrightarrow {}^{30}_{15}\text{P} + \text{proton}$

(2) ${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + \text{neutron}$

(3) ${}^{234}_{90}\text{Th} \longrightarrow {}^{234}_{91}\text{Pa} + \beta \text{ particle}$

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

4. **< HKCE 1993 Paper II - 41 >**

$${}^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \longrightarrow {}^{30}_{15}\text{P} + X$$

In the above nuclear reaction, what are the atomic number and mass number of X ?

	Atomic number	Mass number
A.	−1	0
B.	−1	1
C.	0	1
D.	1	0

5. **< HKCE 1996 Paper II - 37 >**

In the below nuclear reactions, what do X, Y and Z represent ?

(1) ${}^{210}_{84}\text{Po} \longrightarrow {}^{206}_{82}\text{Pb} + X$

(2) ${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + Y$

(3) ${}^{234}_{90}\text{Th} \longrightarrow {}^{234}_{91}\text{Pa} + Z$

	X	Y	Z
A.	an α particle	a proton	a β particle
B.	an α particle	a neutron	a β particle
C.	an α particle	a neutron	γ rays
D.	a β particle	a neutron	γ rays

6. **< HKCE 2004 Paper II - 40 >**

$${}^{2}_{1}\text{H} + {}^{x}_{1}\text{H} \rightarrow {}^{4}_{y}\text{Z} + \text{a neutron}$$

Find the values of x and y in the above nuclear reaction.

	x	y
A.	2	1
B.	2	2
C.	3	1
D.	3	2

7. **< HKCE 2005 Paper II - 26 >**

Which of the following nuclear reactions is a nuclear fusion ?

A. ${}^{235}_{92}\text{U} + \text{n} \longrightarrow {}^{144}_{56}\text{Ba} + {}^{90}_{36}\text{Kr} + 2\,\text{n}$

B. ${}^{14}_{7}\text{N} + \text{n} \longrightarrow {}^{14}_{6}\text{C} + {}^{1}_{1}\text{H}$

C. ${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + \text{n}$

D. ${}^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} + \alpha$

8. **< HKCE 2008 Paper II - 26 >**

Which of the following nuclear reactions is a fission ?

A. ${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{144}_{56}\text{BA} + {}^{89}_{36}\text{Kr} + 3\,{}^{1}_{0}\text{n}$

B. ${}^{238}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{239}_{94}\text{Pu} + 2\,{}^{0}_{-1}\text{e}$

C. ${}^{238}_{92}\text{U} + {}^{14}_{7}\text{N} \longrightarrow {}^{248}_{99}\text{Es} + 4\,{}^{1}_{0}\text{n}$

D. ${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}\text{n}$

9. **< HKCE 2009 Paper II - 27 >**

Which of the following conditions is/are necessary to sustain the chain reaction in the nuclear fission of uranium-235 ?

(1) Each fission produces a large amount of energy.
(2) At least one neutron is released in each fission.
(3) Each fission produces two smaller nuclei.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

10. **< HKCE 2009 Paper II - 24 >**

$${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + \text{n}$$

Which of the following descriptions about the nuclear reaction above is correct ?

A. It is a nuclear fission.
B. It is a nuclear fusion.
C. It is a chain reaction.
D. It is a radioactive decay.

Part B : HKAL examination questions

11. **< HKAL 1980 Paper I - 49 >**

Which of the following equations represent possible nuclear reactions ?

(1) ${}^{10}_{5}\text{B} + \text{neutron} \longrightarrow {}^{6}_{3}\text{Li} + {}^{4}_{2}\text{He}$

(2) ${}^{210}_{83}\text{Bi} \longrightarrow {}^{210}_{84}\text{Po} + \text{beta particle}$

(3) ${}^{14}_{7}\text{N} + {}^{4}_{2}\text{He} \longrightarrow {}^{17}_{8}\text{O} + \text{proton}$

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

12. < HKAL 1992 Paper I - 48 >

$^{14}_{7}N$ + alpha particle $\longrightarrow$ proton + X

In the above nuclear reaction, X represents

A. $^{17}_{8}O$
B. $^{17}_{9}F$
C. $^{17}_{7}N$
D. $^{11}_{6}C$

13. < HKAL 1992 Paper I - 44 >

The main reason why a chain reaction can occur in a nuclear reactor using uranium-235 is that

A. a large quantity of energy is evolved in each fission.
B. the products of nuclear fission are highly radioactive.
C. plutonium is produced and it undergoes further fission.
D. more than 1 neutron is produced when a nucleus undergoes fission.

14. < HKAL 2003 Paper IIA - 43 >

The sun and stars give out their power mainly by

(1) radioactive decay.
(2) nuclear fission.
(3) nuclear fusion.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

15. < HKAL 2004 Paper IIA - 44 >

Two deuterons, $^{2}_{1}H$, combine together form a helium isotope, $^{3}_{2}He$, with the release of energy as shown below.

$$2\,^{2}_{1}H \rightarrow \,^{3}_{2}He + X + \text{energy}$$

Which of the following statements are correct ?

(1) This is an example of nuclear fusion.
(2) The total mass of $^{3}_{2}He$ and X is greater than that of the two $^{2}_{1}H$.
(3) X is a neutron.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

16. < HKAL 2005 Paper IIA - 22 >

The following equation represents a nuclear fission reaction of U-235, producing q neutrons.

$$^{235}_{92}U + \,^{1}_{0}n \longrightarrow \,^{141}_{56}Ba + \,^{92}_{Z}Kr + q\,^{1}_{0}n$$

What are the values of the atomic number Z and the number q ?

	Z	q
A.	37	2
B.	36	2
C.	36	3
D.	34	3

17. < HKAL 2012 Paper IIA - 45 >

Which of the following nuclear reactions are accompanied with a mass defect ?

(1) the union of hydrogen isotopes to form helium

$$^{2}_{1}H + \,^{3}_{1}H \longrightarrow \,^{4}_{2}He + \,^{1}_{0}n$$

(2) the natural radioactive decay of radium-226

$$^{226}_{88}Ra \longrightarrow \,^{222}_{86}Rn + \,^{4}_{2}He$$

(3) the emission of a β-particle from a nucleus

$$^{1}_{0}n \longrightarrow \,^{1}_{1}H + \,^{0}_{-1}e$$

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

18. < HKAL 2013 Paper IIA - 44 >

The sun radiates energy at a constant rate of 4.0×10^{26} W by a nuclear fusion process. The mass of the sun is 2.0×10^{30} kg. Estimate the lifetime of the sun if 0.07% of its mass is converted into radiation energy during the sun's lifetime.

Given : 1 year = 3.15×10^{7} s

A. 1.0×10^{6} years
B. 1.0×10^{10} years
C. 1.0×10^{12} years
D. 1.0×10^{17} years

Part C : Supplemental exercise

19. In which type of nuclear reaction are the daughter nuclei heavier than the mother nuclei ?

A. α-decay
B. β-decay
C. γ-emission
D. nuclear fusion

20. A worker at a nuclear plant walks into a room and is accidentally exposed to a small amount of radiation. The worker will

A. lose consciousness.
B. feel very hot.
C. feel painful.
D. feel no effect.

21. In the Sun, energy is released when hydrogen nuclei collide and form heavier nuclei. This process is called

A. diffusion.
B. fission.
C. fusion.
D. ionization.

22. In a particular chain reaction, a neutron collides with a heavy nucleus. The nucleus then splits to give two lighter nuclei, energy and

A. alpha particles.
B. beta particles.
C. protons.
D. neutrons.

23. Which of the following show(s) nuclear fission ?

(1) $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$

(2) $^{241}_{94}Pu \longrightarrow ^{237}_{92}U + ^{4}_{2}He$

(3) $^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{2}He$

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

24. A U-235 nucleus will split when it captures

A. an alpha particle.
B. a beta particle.
C. a neutron.
D. a proton.

25. The Sun releases its energy mainly by

(1) radioactive decay.
(2) nuclear fission.
(3) nuclear fusion.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

26. The following equations represent some typical nuclear reactions :

(I) $^{9}_{4}Be + ^{1}_{1}H \longrightarrow ^{6}_{3}Li + ^{4}_{2}He$

(II) $^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$

(III) $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{148}_{57}La + ^{85}_{35}Br + 3\,^{1}_{0}n$

Which of the following descriptions of these reactions is/are correct ?

(1) Reaction (I) represents an α-decay.
(2) Reaction (II) represents a nuclear fusion.
(3) Reaction (III) represents a nuclear fission.

A. (1) only
B. (1) & (2) only
C. (2) & (3) only
D. (1), (2) & (3)

27. The main reason why a chain reaction can occur in a nuclear reactor using uranium is that

A. a large amount of energy is released in each fission.
B. the products of nuclear fission are highly radioactive.
C. uranium splits into two smaller fragments.
D. fission neutrons are produced

28. If there were accident in a nearby nuclear power plant, which of the following is NOT the way that the radioactive substances released in the accident can spread to the neighbouring lands ?

A. By wind
B. By rain water
C. By animals
D. By plants

29. Which of the following is NOT the disadvantage of using nuclear energy ?

A. The capital investment of a nuclear power plant is very large.
B. There must be leakage of radiation in a nuclear power plant.
C. Once accident occurs, it would be very serious.
D. The disposal of radioactive waste is a difficult problem.

30. Which of the following do(es) NOT make use of nuclear fusion ?

(1) A nuclear bomb
(2) A hydrogen bomb
(3) Emission of light by a star

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

31. Which of the followings are the advantages of using nuclear energy ?

(1) Nuclear energy causes less pollution to our environment.
(2) The running cost of power plant using nuclear energy is lower.
(3) Nuclear energy is the only choice other than the use of fossil fuel.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

32. Which of the following are the advantages of using nuclear fusion to generate electricity ?

(1) The fuel for nuclear fusion is hydrogen which has unlimited supply in oceans.
(2) The waste products in nuclear fusion are not radioactive.
(3) The nuclear fusion takes place at a very high temperature.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

33. Which of the following are the difficulties to use nuclear fusion for generating electricity ?

(1) Nuclear fusion can only take place at a very high temperature.

(2) No physical container can withstand the high temperature that fusion occurs.

(3) It is difficult to dispose the waste products of the fusion.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

34. Which of the following nuclear reactions is/are an example of fusion ?

(1) ${}^{226}_{88}\text{Ra} \longrightarrow {}^{222}_{86}\text{N} + {}^{4}_{2}\text{He} + \text{energy}$

(2) ${}^{14}_{6}\text{C} \longrightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\text{e} + \text{energy}$

(3) ${}^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \longrightarrow {}^{3}_{2}\text{He} + {}^{1}_{0}\text{n} + \text{energy}$

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

35. Which of the following nuclear reactions is an example of fusion ?

A. Carbon-14 decaying to nitrogen and an electron
B. Two heavy hydrogen nuclei becoming helium and a neutron
C. Radium-226 decaying to radon-222 and an alpha particle
D. Sodium-24 decaying to magnesium-24 and a beta particle

36. In the following nuclear decay :

$${}^{24}_{11}\text{Na} \longrightarrow {}^{24}_{12}\text{Mg} + {}^{0}_{-1}\beta$$

Given the data below :

mass of ${}^{24}_{11}\text{Na}$ = 23.99096 u

mass of ${}^{24}_{12}\text{Mg}$ = 23.98504 u

energy released in the decay = 5.00216 MeV

Calculate the rest mass of the beta particle released.

A. 0.00025 u
B. 0.00055 u
C. 0.00085 u
D. 0.00952 u

37. A star releases energy by nuclear fusion continuously. The mass of the star decreases by 2×10^{16} kg in one year. Calculate the average power released by the star.

A. 5.7×10^{25} W
B. 6.9×10^{25} W
C. 7.2×10^{25} W
D. 8.6×10^{25} W

Part D : HKDSE examination questions

38. **< HKDSE Sample Paper IA - 34 >**

Which of these is a nuclear fusion reaction ?

A. ${}^{235}_{92}\text{U} + \text{n} \longrightarrow {}^{144}_{56}\text{Ba} + {}^{90}_{36}\text{Kr} + 2\text{n}$

B. ${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + \text{n}$

C. ${}^{14}_{7}\text{N} + \text{n} \longrightarrow {}^{14}_{6}\text{C} + {}^{1}_{1}\text{H}$

D. ${}^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} + \alpha$

39. **< HKDSE Practice Paper IA - 36 >**

For the following nuclear reaction, state the type of reaction and determine the energy released.

$${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}\text{n}$$

Given : mass of ${}^{2}_{1}\text{H}$ = 2.014 u

mass of ${}^{3}_{1}\text{H}$ = 3.016 u

mass of ${}^{4}_{2}\text{He}$ = 4.003 u

mass of ${}^{1}_{0}\text{n}$ = 1.009 u

	Type of reaction	Energy released
A.	fusion	0.018 MeV
B.	fusion	16.76 MeV
C.	fission	0.018 MeV
D.	fission	16.76 MeV

40. **< HKDSE 2013 Paper IA - 36 >**

The sun releases huge amount of energy through thermonuclear fusion while at the same time its mass decreases. The average power released by the sun is about 3.8×10^{26} W. Estimate the decrease in mass of the sun in one second.

A. 4.2×10^{6} kg
B. 4.2×10^{9} kg
C. 1.3×10^{15} kg
D. 1.3×10^{18} kg

41. **< HKDSE 2014 Paper IA - 33 >**

A radium nucleus decays to a radon nucleus by emitting an α-particle. The energy released in the process is 4.9 MeV. Compared to the mass of a radium nucleus, the total mass of a radon nucleus and an α-particle is

A. 5.4×10^{-11} kg less.
B. 5.4×10^{-11} kg more.
C. 8.7×10^{-30} kg less.
D. 8.7×10^{-30} kg more.

42. < **HKDSE 2015 Paper IA - 31** >

Which of the following nuclear reactions is/are spontaneous reaction(s) ?

(1) $^{24}_{11}Na \rightarrow ^{24}_{12}Mg + ^{0}_{-1}e$

(2) $^{10}_{5}B + ^{1}_{0}n \rightarrow ^{7}_{3}Li + ^{4}_{2}He$

(3) $^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

43. < **HKDSE 2017 Paper IA - 33** >

The following shows the decay of uranium-238 ($^{238}_{92}U$).

$$^{238}_{92}U \longrightarrow ^{234}_{90}Th + ^{4}_{2}He$$

Given that : mass of $^{238}_{92}U$ = 238.05079 u

mass of $^{234}_{90}Th$ = 234.04363 u

mass of $^{4}_{2}He$ = 4.00260 u

Which of the following statements is/are correct ?

(1) The temperature required to start the decay is about 10^7 K.

(2) The energy released in the decay of one uranium-238 nucleus is 4.25 MeV.

(3) All the energy released in the decay becomes the kinetic energy of $^{4}_{2}He$.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

44. < **HKDSE 2018 Paper IA - 31** >

Which of the following nuclear reactions is/are possible for a chain reaction to occur ?

(1) $^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{1}_{0}n + ^{4}_{2}He$

(2) $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$

(3) $^{239}_{94}Pu + ^{1}_{0}n \longrightarrow ^{148}_{58}Ce + ^{89}_{36}Kr + 3\,^{1}_{0}n$

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

45. < **HKDSE 2018 Paper IA - 33** >

Given: mass of proton = 1.007276 u

mass of neutron = 1.008665 u

mass of $^{3}_{2}He$ nucleus = 3.016030 u

When a $^{3}_{2}He$ nucleus is formed from 2 protons and 1 neutron,

A. 6.7 MeV energy is released.
B. 6.7 MeV energy is required.
C. 8.0 MeV energy is released.
D. 8.0 MeV energy is required.

There is question in next page

M.C. Answers

1. A	11. D	21. C	31. A	41. C
2. D	12. A	22. D	32. A	42. A
3. D	13. D	23. A	33. A	43. B
4. C	14. B	24. C	34. B	44. D
5. B	15. B	25. B	35. B	45. A
6. D	16. C	26. C	36. B	**46. C**
7. C	17. D	27. D	37. A	
8. A	18. B	28. D	38. B	
9. B	19. D	29. B	39. B	
10. B	20. D	30. A	40. B	

M.C. Solution

1. A

$^{27}_{13}Al + ^{4}_{2}He \rightarrow ^{30}_{15}P + ^{1}_{0}X$

Mass number = 1

Atomic number = 0

2. D

×	(1)	$^{10}_{5}B + ^{1}_{0}n \rightarrow ^{6}_{3}Li + ^{4}_{2}He$	Mass number is not balanced.
✓	(2)	$^{210}_{83}Bi \rightarrow ^{210}_{84}Po + ^{0}_{-1}e$	Both mass number and atomic number are balanced.
✓	(3)	$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}p$	Both mass number and atomic number are balanced.

3. D

×	(1)	$^{27}_{13}Al + ^{4}_{2}He \rightarrow ^{30}_{15}P + ^{1}_{1}p$	Atomic number is not balanced.
✓	(2)	$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$	Both mass number and atomic number are balanced.
✓	(3)	$^{231}_{90}Th \rightarrow ^{231}_{91}Pa + ^{0}_{-1}e$	Both mass number and atomic number are balanced.

4. C

Balancing the equation, $^{27}_{13}Al + ^{4}_{2}He \rightarrow ^{30}_{15}P + ^{1}_{0}X$

Atomic number = 0

Mass number = 1

5. B

(1) $^{210}_{84}\text{Po} \rightarrow ^{206}_{82}\text{Pb} + ^{4}_{2}\text{He}$ X: α particle

(2) $^{2}_{1}\text{H} + ^{3}_{1}\text{H} \rightarrow ^{4}_{2}\text{He} + ^{1}_{0}n$ Y: neutron

(3) $^{234}_{90}\text{Th} \rightarrow ^{234}_{91}\text{Pa} + ^{0}_{-1}e$ Z: β particle

6. D

The symbol of neutron is $^{1}_{0}\text{n}$

Balance the mass number : $2 + x = 4 + 1$ $\therefore x = 3$

Balance the atomic number : $1 + 1 = y + 0$ $\therefore y = 2$

7. C

× A. This is an example of nuclear fission.

× B. This is an example of bombardment of particle into a nucleus.

✓ C. Fusion is the combination of two smaller nuclei : H-2 and H-3 to form a larger nucleus : He-4.

× D. This is an example of alpha decay.

8. A

✓ A. It is a typical fission of U-235, triggered by a neutron.

× B. It is a bombardment of particle reaction.

× C. It is a bombardment of particle reaction.

× D. It is a fusion.

9. B

× (1) Fission would produce a large amount of energy, but the energy cannot sustain the chain reaction.

✓ (2) In each fission, neutrons are produced and these neutrons can trigger the further fission of U-235, thus the chain reaction can be sustained.

× (3) Fission produces two smaller nuclei, but these smaller nuclei cannot sustain the further fission.

10. B

As the reaction involves the combination of H-2 and H-3 to become He-4, it is a fusion reaction.

11. D

× (1) $^{10}_{5}\text{B} + ^{1}_{0}n \rightarrow ^{6}_{3}\text{Li} + ^{4}_{2}\text{He}$ Mass number is not conserved.

✓ (2) $^{210}_{83}\text{Bi} \rightarrow ^{210}_{84}\text{Po} + ^{0}_{-1}e$ Both mass number and charge are conserved.

✓ (3) $^{14}_{7}\text{N} + ^{4}_{2}\text{He} \rightarrow ^{17}_{8}\text{O} + ^{1}_{1}p$ Both mass number and charge are conserved.

12. A

Balancing the mass number and atomic number : $^{14}_{7}\text{N} + ^{4}_{2}\text{He} \rightarrow ^{1}_{1}p + ^{17}_{8}\text{O}$.

13. D

Neutrons can trigger the further fissions of the remaining U-235 nuclei, thus maintain the chain reaction

14. B

× (1) The energy released in decay is negligible compared with that in nuclear fission or fusion.

× (2) Nuclear fission occurs for element of very high atomic number. The sun and stars do not contain these elements.

✓ (3) The sun and stars contain mainly hydrogen and helium for nuclear fusion to take place.

15. B

✓ (1) Small nuclei $^{2}_{1}\text{H}$ combining to form large nuclei $^{3}_{2}\text{He}$ is a fusion process.

× (2) Since energy is released, there must be mass defect. Thus the total mass of the product should be smaller.

✓ (3) $2\,^{2}_{1}\text{H} \rightarrow ^{3}_{2}\text{He} + ^{1}_{0}\text{X}$ $\therefore$ X is a neutron.

16. C

① $235 + 1 = 141 + 92 + q$

② $92 + 0 = 56 + z + 0$

$\therefore z = 36$ and $q = 3$

17. D

✓ (1) Since energy is released in this nuclear fusion, thus there is mass defect.

✓ (2) Since energy is released and becomes the kinetic energy of α-particle, there is mass defect.

✓ (3) Since energy is released and becomes the kinetic energy of β-particle, there is mass defect.

18. B

$E = mc^2 = (2.0 \times 10^{30} \times 0.07\%) \times (3 \times 10^8)^2 = 1.26 \times 10^{44}$ J

$E = Pt$

$\therefore (1.26 \times 10^{44}) = (4.0 \times 10^{26})\,t$ $\therefore t = 3.15 \times 10^{17}$ s $= 1 \times 10^{10}$ years

19. D

× A. After α-decay, the daughter nucleus has its mass number decreased by 4.

× B. After β-decay, the daughter nucleus has its mass slightly decreased due to mass defect.

× C. After γ-emission, the mass of the nucleus is slightly decreased due to mass defect.

✓ D. After nuclear fusion, the nucleus is heavier since it consists of smaller nuclei combining together.

20. D

There is no immediate effect on a worker who is exposed to small amount of radiation.

However, the radiation is accumulative in the human body and thus increases the chance of cancer in the future.

21. C

The Sun makes use of nuclear fusion to give out solar energy.

22. D

After nuclear fission, 2, 3 or 4 fission neutrons may be produced to cause further fission, thus give the chain reaction.

23. A

✓ (1) It is a typical fission of U-235.
× (2) It is an α-decay.
× (3) It is fusion.

24. C

When a neutron is captured by a U-235 nucleus, the neutron will trigger the fission of the uranium nucleus.

25. B

× (1) The Sun does not contain radioactive nuclei to give radioactive decay.
× (2) The Sun does not contain large nuclei to give fission.
✓ (3) The Sun contains mainly hydrogen that undergoes fusion to give out solar energy.

26. C

× (1) Reaction (I) is the bombardment of proton on the Be-9 nucleus to give two other nuclei.
✓ (2) The combination of two smaller nuclei to give a large nucleus is called fusion.
✓ (3) The split up of a large nucleus to give two smaller nuclei is called fission.

27. D

The fission neutrons can trigger further fissions of the remaining uranium nuclei to give the chain reaction.

28. D

✓ A. Wind can carry the radioactive waste from one place to another place.
✓ B. Rain water can carry the radioactive waste from one place to flow to another place.
✓ C. Animals can bring the radioactive waste and move to another place.
× D. Since plants cannot move, they cannot carry radioactive waste from one place to another place.

29. B

✓ A. Building a nuclear power plant is very expensive to ensure every safety measure.
× B. A good design of nuclear power plant ensures no leakage of radiation to the environment.
✓ C. If explosion occurs in a nuclear power plant, it would cause disastrous effect to the environment.
✓ D. Since the wastes of fission product are radioactive, their disposal causes a series problem.

30. A

✓ (1) A nuclear bomb makes use of nuclear fission, NOT nuclear fusion.
× (2) A hydrogen bomb indeed makes use of nuclear fusion of hydrogen to give out energy.
× (3) A star, likes the Sun, makes use of nuclear fusion to give out energy.

31. A

✓ (1) Nuclear energy makes use of fission does not produce air pollution.
✓ (2) Nuclear energy is cheaper once the chain reaction starts.
× (3) Other than the fossil fuels, there are renewable energy resources such as solar energy, wind energy and hydroelectric energy.

32. A

✓ (1) In ocean, there is unlimited supply of water that consists of hydrogen.
✓ (2) The water products in nuclear fusion are helium which are noble gas and not radioactive.
× (3) Fusion takes place at high temperature is a disadvantage, not advantage.

33. A

✓ (1) Nuclear fusion takes place at very high temperature; it is not easy to produce such a high temperature.
✓ (2) Even the high temperature (about 10 000 000°C) is achieved, all containers will change to gases.
× (3) The waste products of fusion is clean and not radioactive, and thus no disposal problem.

34. B

× (1) It is an example of α-decay.
× (2) It is an example of β-decay.
✓ (3) It is an example of nuclear fusion.

35. B

Fusion is combining two smaller nuclei (hydrogen nuclei) to form a large nucleus (the helium).

36. B

As 1 u is equivalent to 931 MeV,

mass equivalent of the energy released $= \dfrac{5.00216}{931} = 0.00537$ u

By conservation of mass and energy,

$23.99096 = 23.98504 + m_\beta + 0.005373$

$\therefore\ m_\beta = 0.00055$ u

37. A

By $\Delta E = \Delta m c^2$

$\therefore \Delta E = (2 \times 10^{16}) \times (3 \times 10^8)^2 = 1.8 \times 10^{33}$ J

Assume 365 days in 1 year.

Average power : $P = \frac{E}{t} = \frac{1.8 \times 10^{33}}{365 \times 24 \times 3600} = 5.7 \times 10^{25}$ W

38. B

× A. This is an example of nuclear fission.

✓ B. Fusion is the combination of two smaller nuclei : H-2 and H-3 to form a larger nucleus : He-4.

× C. This is an example of bombardment of particle into a nucleus.

× D. This is an example of alpha decay.

39. B

Since the reaction is to combine two hydrogen nuclei into a helium nucleus, it is a fusion reaction.

Mass defect = 2.014 + 3.016 − 4.003 − 1.009 = 0.018 u

Energy released = 0018 × 931 = 16.76 MeV

40. B

In 1 second, energy released is 3.8×10^{26} J.

By $\Delta E = \Delta m c^2$

$\therefore (3.8 \times 10^{26}) = \Delta m (3 \times 10^8)^2 \quad \therefore \Delta m = 4.2 \times 10^9$ kg

41. C

By Einstein's equation :

$\Delta E = \Delta m c^2$

$\therefore (4.9 \times 10^6 \times 1.6 \times 10^{-19}) = \Delta m \times (3 \times 10^8)^2 \qquad \therefore \Delta m = 8.7 \times 10^{-30}$ kg

Since energy is released, there is mass defect.

Thus, the total mass of the daughter nucleus Y and α-particle is less than the mother nucleus.

42. A

✓ (1) This is a beta-decay reaction, which is spontaneous.

× (2) This is a bombardment reaction, triggered by the hitting of neutron onto the nucleus B-10.

× (3) This is a fusion reaction, which occurs when the temperature is high enough.

43. B

× (1) The decay is spontaneous, can take place in any temperature.

✓ (2) Mass defect : Δm = 238.05079 − 234.04363 − 4.00260 = 0.00456 u
Energy released : E = 0.00456 × 931 = 4.25 MeV

× (3) The energy released in the decay will become the kinetic energy of both Th and He.

44. D

× (1) Chain reaction only occurs in nuclear fission. This is a nuclear fusion, chain reaction does not occur.

✓ (2) There are 3 fission neutrons that can trigger the remaining U-235 to give chain reaction.

✓ (3) There are 3 fission neutrons that can trigger the remaining Pu-239 to give chain reaction.

45. A

Mass defect = 1.007276 × 2 + 1.008665 − 3.016030 = 0.007187 u

Energy released = 0.007187 × 931 = 6.7 MeV

Use the following data wherever necessary :

Speed of light in vacuum	$c = 3 \times 10^8$ m s^{-1}	
Charge of an electron	$e = 1.60 \times 10^{-19}$ C	
Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}	
Atomic mass unit	u = 1.661×10^{-27} kg	(1 u is equivalent to 931 MeV)

The following list of formulae may be found useful :

Half-life and decay constant	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$
Activity and the number of undecayed nuclei	$A = kN$
Mass-energy relationship	$\Delta E = \Delta m\, c^2$

Part A : HKCE examination questions

1. **< HKCE 2003 Paper I - 9 >**

In 1986, a disastrous nuclear accident happened at the Chernobyl Nuclear Station. A large amount of radioactive substance was released and spread to neighbouring countries. The radiation levels recorded in these countries were much higher than the normal background count rate.

(a) State **two** sources of background radiation. (2 marks)

(b) State one way by which the radioactive substances released in the accident were spread to neighbouring countries. (1 mark)

(c) One of the radioactive isotopes released in the accident was caesium-137 (Cs-137). The following equation shows how Cs-137 is produced :

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{137}_{x}\text{Cs} + {}^{y}_{37}\text{Rb} + z\,{}^{1}_{0}\text{n}$$

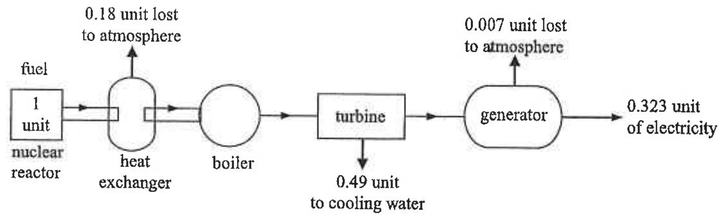
(i) If $z = 4$, find the values of x and y and state their physical meanings. (4 marks)

(ii) The half-life of Cs-137 is 30 years. Suppose that a soil sample contaminated by Cs-137 is 30 years was found to have an initial activity of 1.2×10^6 Bq (disintegrations per second). A physicist comments that the contaminated sample will affect the environment for more than 300 years. Justify the physicist's claim with calculations. You may assume that the activity of a non-contaminated sample of similar nature is 200 Bq. (3 marks)

1. (d) The development of nuclear energy is a controversial issue. Do you support the development of nuclear energy ? State the reasoning to support your point of view. (4 marks)

Part B : HKAL examination questions

2. **< HKAL 1983 Paper IIB - 7 >**



In a nuclear reactor using U-235 as fuel, 1 unit of fission energy produced would undergo the changes shown in the above figure, that finally 0.323 unit of electrical energy is obtained.

(a) Suppose the electrical power output of this plant is 1066 MW.

(i) Calculate the total power generated by the reactor. (1 mark)

(ii) Find the total power lost to the atmosphere. (1 mark)

(b) The turbine is cooled by circulating water through it at the rate of 48 m^3 s^{-1}. Calculate the rise in temperature of the cooling water. (Density of water = 10^3 kg m^{-3}, specific heat capacity of water = 4200 J kg^{-1} K^{-1}) (3 marks)

(c) In the reactor, energy is produced by the fission of uranium-235 atoms.

$$^{235}\text{U} + \text{n} \longrightarrow {}^{141}\text{Ba} + {}^{92}\text{Kr} + 3\,\text{n}$$

Given : ^{235}U = 235.0409 u ; ^{141}Ba = 140.9141u ; ^{92}Kr = 91.9250 u ; n = 1.0086 u.

Calculate the number of uranium atoms which undergo fission in 1 s. (3 marks)

(d) The nuclear plant is designed to produce power continuously for 10 years without refuelling. Estimate the mass of uranium-235 required. Given that the molar mass of U-235 is 235 g. (2 marks)

3. < HKAL 1993 Paper IIB - 12 >

The following equation represents one of the nuclear reaction in a fission reactor :

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{91}_{36}Kr + ^{142}_{56}Ba + 3\,^{1}_{0}n$$

Given : the mass of one nucleus of $^{235}_{92}U$ = 235.0439 u

$^{91}_{36}Kr$ = 90.9234 u

$^{142}_{56}Ba$ = 141.9164 u

$^{1}_{0}n$ = 1.0087 u

(a) According to the above equation, find the mass defect between the reactants and products when one $^{235}_{92}U$ nucleus undergoes fission. (2 marks)

(b) If 4.00×10^{-5} kg of $^{235}_{92}U$ undergoes fission in one second, calculate the rate of energy production. Take the mass of one mole of $^{235}_{92}U$ as 235 g. (3 marks)

4. < HKAL 1998 Paper IIB - 5 >

A reaction which takes place in a nuclear reactor is shown by the following equation :

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{142}_{56}Ba + ^{91}_{36}Kr + 3\,^{1}_{0}n + 173.8 \text{ MeV}$$

Mass of one nuclide of $^{235}_{92}U$ = 235.0439 u

Mass of one nuclide of $^{142}_{56}Ba$ = 141.9164 u

Mass of one nuclide of $^{91}_{36}Kr$ = 90.9234 u

(a) Calculate the mass of a neutron, express the answer in atomic mass unit. (3 marks)

(b) The fuel in the reactor contain 1.0×10^{4} kg of U-235. Calculate the total energy released when all the U-235 nuclei in the fuel have undergone fission. Take the mass of one mole of U-235 as 235 g. (3 marks)

(c) If the average power output of the reactor is 500 MW and the efficiency of conversion of nuclear energy to electrical energy is 40%, estimate the time for which the fuel can be used. (2 marks)

5. < HKAL 2002 Paper I - 7 >

The energy released by the Sun is the result of nuclear fusion in its core, where hydrogen are fused together into helium nuclei through a complicated process. The overall reaction can be simplified by the following equation :

$$4\,^{1}_{1}H \longrightarrow ^{4}_{2}He + \text{other particles of negligible mass} + \text{energy}$$

(a) Why is the above process of forming helium nuclei from protons very difficult to achieve on Earth, but easily achieved at the Sun's core ? (2 marks)

(b) Given : mass of hydrogen = 1.00728 u

mass of helium = 4.00150 u

Calculate the energy released in each fusion by the Sun. Express your answer in joule. (2 marks)

(c) Calculate the total energy released by the Sun for every kilogram of hydrogen fused to form helium nuclei. Take the mass of one mole of hydrogen ($^{1}_{1}H$) be 1 g. (2 marks)

6. < HKAL 2010 Paper I - 4 >

A nucleus of radon ($^{222}_{86}Rn$) decays to an isotope of polonium (Po) by emitting an α-particle.

Given : mass of a radon nucleus = 222.0176 u

mass of a polonium nucleus = 218.0090 u

mass of an α-particle = 4.0026 u

(a) Write an equation for the decay and find the energy released, in MeV, in the decay. (3 marks)

(b) The energy released in the decay becomes the kinetic energy of the decay products. Explain quantitatively why the α-particle takes most of the decay energy. Assume that the parent nucleus is at rest initially. (2 marks)

(c) Hence calculate the speed v of the α-particle, assume all the decay energy is transferred to the α-particle. (2 marks)

7. < HKAL 2012 Paper I - 6 >

Iodine-131 ($^{131}_{53}I$) is a common radioactive nuclide found in radioactive waste from nuclear power plants. It undergoes β decay and becomes a stable nuclide Xenon-131 (^{131}Xe) with a half-life of 8.02 days.

(a) Write down the decay equation of Iodine-131. (1 mark)

(b) (i) Estimate the initial activity of 1 kg of Iodine-131 in Bq. (3 marks)

Given : mass of one mole of Iodine-131 = 131 g

(ii) Assuming that all the decay energy of Iodine-131 becomes heat, find the initial heating power of 1 kg of Iodine-131 in the unit W. (4 marks)

Given : mass of an Iodine-131 nucleus = 130.90612 u

mass of a Xenon-131 nucleus = 130.90508 u

mass of an electron = 0.00054 u

(c) Even after a reactor is shut down and nuclear fission is completely stopped, fission products like Iodine-131 keep on producing heat. Explain why we cannot stop the Iodine-131 from producing heat. (2 marks)

(d) Iodine-123 is another radioactive isotope of Iodine. It emits γ rays and has a half-life of 13 hours. As thyroid in the human body readily absorbs iodine, Iodine-123 is commonly used as a medical tracer for diagnosis of thyroid diseases. Give ONE reason why Iodine-123 is more suitable to be used as medical tracer than Iodine-131. (1 mark)

Part C : Supplemental exercise

8. (a) When an alpha particle strikes a beryllium $\left(^{9}_{4}Be\right)$ nucleus, one carbon $\left(^{12}_{6}C\right)$ nucleus and one particle Q are formed. Write down the nuclear equation. What is the particle Q ? (3 marks)

(b) A nuclear power plant makes use of nuclear fission of uranium to generate electrical power at a rate of 500 MW. The internal energy that can be extracted from 1 kg of uranium fuel in the fission reactor is about 5.6×10^{12} J. The efficiency of energy conversion to electrical form in the nuclear reactor is only 30%. (1 MW = 10^6 W)

(i) What is the electrical energy supplied in one day ? (2 marks)

(ii) If electrical energy costs $0.9 for 1 kWh, how much does it cost for the electrical energy generated in one day ? (4 marks)

(iii) Calculate the electrical energy that can be produced by 1 kg of uranium in the fuel rod. (2 marks)

(iv) Find the mass of uranium fuel used in one day. (2 marks)

(c) Some people propose that nuclear energy should eventually replace oil and coal as sources of energy supply. Do you agree with this ? List 3 reasons to support your argument. (4 marks)

9. In a nuclear reactor for generating electricity, Uranium-235 undergoes fission to generate energy.

(a) Describe the process of nuclear fission of Uraniuim-235. (3 marks)

(b) The waste products from a nuclear reactor contain isotopes which are radioactive and emit β radiation. They are stored in sealed metal cans for 200 years until the activity decreases to 400 Bq that can be disposed of.

(i) Explain how these isotopes are produced. (2 marks)

(ii) What is meant by the term radioactive ? (2 marks)

(iii) State the reasons why metal cans are used to store the waste products. (1 mark)

(iv) It is known that the half life of the radioactive isotope in the metal cans is 25 years. What is the initial activity of the waste products in the cans ? (3 marks)

(v) Calculate the initial number of atoms of the radioactive isotope in the metal cans. (3 marks)

(c) David wonders why nuclear fusion is not used to generate electricity. Suggest two reasons to explain this. (2 marks)

Part D : HKDSE examination questions

10. **< HKDSE Sample Paper IB - 14 >**

In April 1986, a disastrous nuclear accident happened at the Chernobyl Nuclear Power Station. A large quantity of various radioactive substances was released and spread to neighbouring countries. The radiation levels recorded in these countries were much higher than the normal background radiation count rate.

(a) State ONE source of background radiation.

(b) One of the radioactive isotopes released in the accident was caesium-137 (Cs-137). The following equation shows how Cs-137 is produced :

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{137}_{55}Cs + ^{95}_{37}Rb + x\,^{1}_{0}n$$

Given : mass of one nuclide of $^{235}_{92}U$ = 235.0439 u
$^{137}_{55}Cs$ = 136.9071u
$^{95}_{37}Rb$ = 94.9399 u
$^{1}_{0}n$ = 1.0087 u.

(i) What is the value of x ? (1 mark)

(ii) Find the energy release in the fission of one U-235 nuclide in MeV. (2 marks)

(iii) The half-life of Cs-137 is 30 years. A soil sample contaminated by Cs-137 has an activity of 1.2×10^6 Bq. A physicist comments that the contaminated sample will affect the environment for more than 350 years. Justify the physicist's claim with calculations. It is known that the activity of an uncontaminated soil sample is 200 Bq. (2 marks)

11. **< HKDSE 2012 Paper IB - 11 >**

Radium-226 ($^{226}_{88}Ra$) undergoes α-decay into radon (Rn).

(a) Write a nuclear equation for the decay. (2 marks)

11. (b) Given : mass of a radium nucleus = 226.0254 u
mass of a radon nucleus = 222.0176 u
mass of an α-particle = 4.0026 u

Calculate the energy released in the decay in MeV. (2 marks)

(c) 1 curie (Ci) is defined as the activity of 1 g of radium. The activity of a radium source used in laboratories is about 5 μCi. Estimate the number of radium atoms in this source and hence find its activity expressed in disintegrations per second. The half-life of radium-226 is 1600 years and take the mass of one mole of radium as 226 g.
(1 μCi = 1×10^{-6} Ci) (3 marks)

12. < HKDSE 2015 Paper IB - 10 >

Scientists had been experimenting controlled fusion in a nuclear reactor in which deuterium ($^2_1$H) and tritium ($^3_1$H) undergo the following nuclear fusion :

$$^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n} + \text{energy released}$$

Given : mass of a deuterium nucleus = 2.014102 u
mass of a tritium nucleus = 3.016049 u
mass of a helium nucleus = 4.002602 u
mass of a neutron = 1.008665 u

(a) Calculate the energy released, in MeV, in the above nuclear fusion. (2 marks)

(b) In the nuclear reactor, deuterium and tritium exist as plasma, which is a mixture of ions at a very high temperature. To start the fusion reaction, the average kinetic energy of the ions in the plasma has to reach the minimum value of 0.2 MeV.

(i) Explain why a very high temperature is needed for nuclear fusion to occur. (2 marks)

(ii) Estimate the order of magnitude of the minimum temperature at which fusion of deuterium and tritium nuclei would be possible if the plasma can be regarded as an ideal gas. (2 marks)

There is question in next page

HKEAA's Marking Scheme is prepared for the markers' reference. It should not be regarded as a set of model answers. Students and teachers who are not involved in the marking process are advised to interpret the Marking Scheme with care.

Question Solution

1. (a) Any **TWO** of the following : [2]
   * Cosmic radiation from the space
   * Radiation from rocks
   * Radiation in air
   * Radiation from food
   * Radiation from our body

(b) Any **ONE** of the following : [1]
   * by wind
   * by rain
   * by water in river
   * by imported food

(c) (i) $x = 92 - 37 = 55$ [1]
$y = 235 + 1 - 137 - 4 = 95$ [1]
x is the atomic number of Cs [1]
y is the mass number of Rb [1]

(ii) Number of half-life in 300 years = 10 [1]
Activity after 10 half-lives = $(1.2 \times 10^6) \times (\frac{1}{2})^{10}$ = 1172 Bq [1]
After 300 years, the activity is still higher than that of non-contaminated sample, thus his claim is correct. [1]

OR

By $A = A_0 \left(\frac{1}{2}\right)^{t/t_{1/2}}$

$\therefore$ $(200) = (1.2 \times 10^6) \times (\frac{1}{2})^{t/30}$ [1]

$\therefore$ t = 377 years [1]

A time longer than 300 years is required for the activity to drop to safe level, thus his claim is correct. [1]

(d) I support the development of nuclear power since
it is cheaper as the running cost is lower, and [2]
it is clean since it does not produce air pollution and acid rain. [2]

OR

I do not support the development of nuclear power since
it is dangerous as once accident occurs, it would be very serious, and [2]
it is expensive as the capital investment is very high. [2]

< accept other reasonable answers >

13. <HKDSE 2019 Ppaper-IB-10>

(a) The equation below represents nuclear fission of uranium-235 (U-235).

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + x\,^{1}_{0}n + 200\ MeV$$

(i) What is the value of x ? (1 mark)

....

(ii) State a necessary condition for chain reaction of fission to occur. (1 mark)

....

....

....

Scientists found evidence in Oklo, Africa that natural nuclear fission occurred two billion (2×10^9) years ago. The uranium mineral ore mined from Oklo at present is found to have 0.6% concentration by mass of U-235 (see the table below), which is much lower than usual.

(b) The table gives the information of U-235 and U-238 in a sample of uranium mineral ore found in Oklo. Given: half-life of U-235 = 7.04×10^8 years

	2×10^9 years ago	at present
U-235	m_0 kg	0.060 kg (i.e. 0.6% concentration by mass)
U-238	13.556 kg	9.940 kg (i.e. 99.4% concentration by mass)

*(i) Estimate the amount m_0 (in kg) of U-235 in the sample 2×10^9 years ago. (2 marks)

(ii) Hence determine whether natural nuclear fission of U-235 was possible 2×10^9 years ago. For fission of U-235 to happen, its concentration by mass in the uranium mineral ore has to be at least 3%. (1 mark)

There must be underground water in the vicinity of this uranium-rich mineral deposit for natural nuclear fission to be possible. Since water can slow down the fast neutrons from fission, these neutrons can easily be captured by U-235.

(c) In fact the chain reaction stopped even before the concentration by mass of U-235 dropped to 3%. Explain why this occurred. (2 marks)

14. < HKDSE 2020 Paper 1B -10>

Given: mass of proton = 1.0073 u
mass of α particle = 4.0015 u
mass of $^{14}_{7}N$ nucleus = 13.9993 u
mass of $^{17}_{8}O$ nucleus = 16.9947 u

When a stationary $^{14}_{7}N$ nucleus is bombarded by an α particle, the following nuclear reaction can be triggered with products $^{17}_{8}O$ and X fly off:

$$\alpha + ^{14}_{7}N \longrightarrow ^{17}_{8}O + X$$

(a) What is X ? (1 mark)

....

*(b) Based on energy consideration, estimate the minimum kinetic energy, in MeV, of the α particle required for such a nuclear reaction to occur. (2 marks)

(c) However, when conservation of momentum is also taken into account, the α particle must possess a kinetic energy greater than that found in (b) to bring about such a reaction. Explain. (2 marks)

2. (a) (i) As 1 unit of nuclear power can only give 0.323 unit of electricity, the efficiency is 32.3%

Power generated by the reactor $= 1066 \div 32.3\%$

$= 3300$ MW [1]

(ii) Power lost to the atmosphere $= 3300 \times (0.18 + 0.007)$

$= 617$ MW [1]

(b) Power delivered to cooling water $= 3300 \times 0.49$

$= 1617$ MW [1]

In 1 s, volume of water circulating is 48 m^3

$\therefore$ mass = volume × density $= 48 \times 10^3$ kg

By $E = m\,c\,\Delta T$ and consider the time of 1 s.

$\therefore\ (1617 \times 10^6) = (48 \times 1000) \times (4200) \times \Delta T$ [1]

$\therefore\ \Delta T = 8$ K [1]

(c) Mass defect :

$\Delta m = (235.0409 + 1.0086) - (140.9141 + 91.9250 + 3 \times 1.0086)$

$= 0.1846$ u [1]

Energy released in each fission :

$E = 0.1846 \times 931 \times 10^6 \times 1.6 \times 10^{-19}$

$= 2.75 \times 10^{-11}$ J [1]

OR

$E = m\,c^2$

$= (0.1846 \times 1.661 \times 10^{-27}) \times (3 \times 10^8)^2$

$= 2.76 \times 10^{-11}$ J [1]

Number of uranium atoms undergoing fission in 1 s :

By $P = \frac{N}{t} E$

$\therefore\ (3300 \times 10^6) = \frac{N}{t} \times (2.75 \times 10^{-11})$

$\therefore\ \frac{N}{t} = 1.20 \times 10^{20}\ s^{-1}$ [1]

(d) Mass of U-235 needed in 1 s $= \frac{1.20 \times 10^{20}}{6.02 \times 10^{23}} \times 0.235$

$= 4.684 \times 10^{-5}$ kg [1]

Mass of U-235 needed in 10 years $= 4.684 \times 10^{-5} \times 10 \times 365 \times 24 \times 3600$

$= 1.48 \times 10^4$ kg [1]

3. (a) Mass defect $= (235.0439\ u) - (90.9234\ u + 141.9164\ u + 2 \times 1.0087\ u)$ [1]

$= 0.1867$ u [1]

(b) Method ① :

$\frac{N}{t} = \frac{4.00 \times 10^{-5}}{0.235} \times 6.02 \times 10^{23} = 1.025 \times 10^{20}\ s^{-1}$ [1]

$P = \frac{N}{t} E = (1.025 \times 10^{20}) \times [0.1867 \times 1.661 \times 10^{-27} \times (3 \times 10^8)^2]$ [1]

$= 2.86 \times 10^9$ W [1]

Method ② :

$\frac{N}{t} = \frac{4.00 \times 10^{-5}}{0.235} \times 6.02 \times 10^{23} = 1.025 \times 10^{20}\ s^{-1}$ [1]

$P = \frac{N}{t} E = (1.025 \times 10^{20}) \times (0.1867 \times 931 \times 10^6 \times 1.6 \times 10^{-19})$ [1]

$= 2.85 \times 10^9$ W [1]

Method ③ :

$P = (4 \times 10^{-5}) \times \frac{0.1867}{235.0439} \times (3 \times 10^8)^2$ [2]

$= 2.86 \times 10^9$ W [1]

4. (a) mass defect : $\Delta m = \frac{173.8}{931} = 0.1867$ u [1]

$\therefore\ 235.0439 = 141.9164 + 90.9234 + 2 \times m_n + 0.1867$ [1]

$\therefore\ m_n = 1.0087$ u [1]

(b) Number of U-235 nuclei $= \frac{1.0 \times 10^4}{0.235} \times 6.02 \times 10^{23} = 2.56 \times 10^{28}$ [1]

Energy released $= 2.56 \times 10^{28} \times 173.8$ MeV [1]

$= 4.45 \times 10^{30}$ MeV **< accept** 7.12×10^{17} J > [1]

(c) Total electrical energy released by the fuel rods $= 4.45 \times 10^{30} \times 10^6 \times 1.6 \times 10^{-19} \times 40\%$

$= 2.848 \times 10^{17}$ J [1]

By $E = P\,t$

$\therefore\ (2.848 \times 10^{17}) = (500 \times 10^6)\,t$

$\therefore\ t = 5.70 \times 10^8$ s **< accept** 1.58×10^5 hours **or** 6590 days **or** 18.1 years > [1]

5. (a) The temperature in the Sun's core is so high that the hydrogen nuclei have sufficient large kinetic energy [1]

to overcome the strong electrostatic repulsion between them. [1]

5. (b) $\Delta m = (4)(1.00728) - 4.00150 = 0.02762$ u [1]

$\Delta E = \Delta m c^2 = (0.02762)(1.661 \times 10^{-27})(3 \times 10^8)^2 = 4.13 \times 10^{-12}$ J [1]

OR

$\Delta E = 0.02762 \times 931 \times 10^6 \times 1.6 \times 10^{-19} = 4.11 \times 10^{-12}$ J [1]

(c) Number of hydrogen atoms in 1 kg of hydrogen $= \dfrac{(1)}{(1 \times 10^{-3})} \times (6.02 \times 10^{23})$

Number of fusion by 1 kg of hydrogen $= \dfrac{(1)}{(1 \times 10^{-3})} \times (6.02 \times 10^{23}) \times \dfrac{1}{4} = 1.505 \times 10^{26}$ [1]

Energy released by 1 kg of hydrogen $= 1.505 \times 10^{26} \times 4.13 \times 10^{-12}$

$= 6.22 \times 10^{14}$ J < accept 6.14×10^{14} J to 6.28×10^{14} J > [1]

6. (a) ${}^{222}_{86}\text{Rn} \longrightarrow {}^{218}_{84}\text{Po} + {}^{4}_{2}\text{He}$ [1]

Mass defect = 222.0176 u − (218.0090 u + 4.0026 u) = 0.006 u [1]

Energy released = 0.006 × 931 = 5.586 MeV < accept 5.59 MeV > [1]

(b) The mass ratio of the products is $m_{Po} : m_{\alpha} = 218 : 4$

By conservation of momentum, the speed ratio is $v_{Po} : v_{\alpha} = 4 : 218$ [1]

The kinetic energy of the products is $KE_{Po} : KE_{\alpha} = \frac{1}{2}(218)(4)^2 : \frac{1}{2}(4)(218)^2 = 4 : 218$ [1]

Thus, most of the energy released is given to the α.

(c) By $E = \dfrac{1}{2} m v^2$

$\therefore (5.586 \times 10^6 \times 1.6 \times 10^{-19}) = \dfrac{1}{2} \times (4.0026 \times 1.661 \times 10^{-27}) v^2$ [1]

$\therefore v = 1.64 \times 10^7$ m s^{-1} [1]

7. (a) ${}^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + {}^{0}_{-1}\text{e}$ < accept ${}^{0}_{-1}\beta$ > [1]

(b) (i) Number of atoms of I-131 in 1 kg $= \dfrac{1}{131 \times 10^{-3}} \times 6.02 \times 10^{23} = 4.60 \times 10^{24}$ [1]

Decay constant of I-131 : $k = \dfrac{\ln 2}{t_{1/2}} = \dfrac{\ln 2}{8.02 \times 24 \times 3600} = 1.00 \times 10^{-6}$ s^{-1} [1]

Initial activity : $A_o = k N_o = (1.00 \times 10^{-6})(4.60 \times 10^{24}) = 4.60 \times 10^{18}$ Bq [1]

7. (b) (ii) $\Delta m = 130.90612 - 130.90508 - 0.00054 = 5 \times 10^{-4}$ u [1]

$E = (5 \times 10^{-4}) \times (931 \times 10^6 \times 1.6 \times 10^{-19})$ [1]

$= 7.45 \times 10^{-14}$ J [1]

OR

$E = \Delta m c^2 = (5 \times 10^{-4} \times 1.661 \times 10^{-27}) \times (3 \times 10^8)^2$ [1]

$= 7.47 \times 10^{-14}$ J [1]

$P = EA = (7.45 \times 10^{-14})(4.60 \times 10^{18})$

$= 3.43 \times 10^5$ W < accept 3.4×10^5 W to 3.5×10^5 W > [1]

(c) The decay of a radioisotope is determined by the half-life (**OR** decay constant). [1]

It cannot be changed by human factors or surrounding factors. [1]

(d) Any **ONE** of the following : [1]

* Iodine-123 emits γ rays that give less harmful effect to human body.
* The half-life of Iodine-123 is shorter, thus give less harmful effect to human body.
* Iodine-123 emits γ rays that have greater penetrating power to be detected outside the human body.

8. (a) ${}^{4}_{2}\text{He} + {}^{9}_{4}\text{Be} \longrightarrow {}^{12}_{6}\text{C} + {}^{A}_{Z}Q$ [1]

$A = 4 + 9 - 12 = 1$ and $Z = 2 + 4 - 6 = 0$ [1]

Q is a neutron [1]

(b) (i) $E = Pt$

$= (500 \times 10^6)(1 \times 24 \times 60 \times 60)$ [1]

$= 4.32 \times 10^{13}$ J [1]

(ii) Unit of electrical energy $= \dfrac{4.32 \times 10^{13}}{3600000}$ [1]

$= 1.2 \times 10^7$ kWh [1]

Cost $= 1.2 \times 10^7 \times \$\,0.9$ [1]

$= \$\,10\,800\,000$ [1]

(iii) Electrical energy produced by 1 kg of uranium $= 5.6 \times 10^{12} \times 30\%$ [1]

$= 1.68 \times 10^{12}$ J [1]

(iv) Mass of uranium fuel used in one day $= \dfrac{4.32 \times 10^{13}}{1.68 \times 10^{12}}$ [1]

$= 25.7$ kg [1]

8. (c) **Agree** [1]

Reasons : (any **THREE** of the following) < accept other reasonable answers > [3]

* Reserves of oil and coal are limited.
* Nuclear energy is cheaper.
* Nuclear energy causes less pollution.
* Nuclear energy does not produce greenhouse gases.

OR

Disagree [1]

Reasons : (any **THREE** of the following) < accept other reasonable answers > [3]

* The capital investment of a nuclear plant is high.
* The disposal of radioactive waste causes a serious problem.
* If there is accident, the damage to public is large.
* Some other resources of energy may be used, e.g. solar energy.

9. (a) When a neutron is captured by a Uranium-235 nucleus, the nucleus undergoes fission. [1]

It then splits into two smaller nuclei and together with some fission neutrons. [1]

During the fission, large amount of energy is released. [1]

(b) (i) These isotopes are produced as the **by-products** [1]

of the **fission** of the Uranium-235. [1]

(ii) Radioactive is used to describe an unstable nucleus [1]

that may emit α, β or γ radiation to form a more stable nucleus. [1]

(iii) Metal cans are used since β radiation cannot pass through the metal. [1]

(iv) Number of half-lives $= \frac{200}{25} = 8$ [1]

Initial activity $= 400 \times 2^8$ [1]

$= 102400$ Bq [1]

(v) Decay constant : $k = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{25 \times 365 \times 24 \times 3600} = 8.79 \times 10^{-10}\ s^{-1}$ [1]

By $A_o = kN_o$ [1]

$\therefore\ (102400) = (8.79 \times 10^{-10})\, N_o$

$\therefore\ N_o = 1.16 \times 10^{14}$ [1]

(c) ① Nuclear fusion can only occur under very high temperature that is not easy to achieve. [1]

② No physical container can withstand the high temperature that fusion occurs. [1]

10. (a) Any ONE of the following : [1]

* cosmic radiation from space
* radiation from rocks
* radiation from air
* radiation from food
* radiation from human bodies

(b) (i) $x = 4$ [1]

(ii) Mass defect $= 235.0439 - (136.9071 + 94.9399 + 3 \times 1.0087) = 0.1708$ u [1]

Energy released $= 0.1708 \times 931$ MeV $= 159$ MeV [1]

(iii) Activity of the sample after 350 years :

$A = (1.2 \times 10^6) \times (\frac{1}{2})^{350/30}$ $\quad\therefore\ A = 369$ Bq [1]

Since the activity is larger than 200 Bq, the claim is correct. [1]

OR

$(200) = (1.2 \times 10^6) \times (\frac{1}{2})^{t/30}$ $\quad\therefore\ t = 377$ years [1]

Since the time for the activity to drop to 200 Bq is longer than 250 years, the claim is correct. [1]

11. (a) $^{226}_{88}Ra \rightarrow\ ^{222}_{86}Rn +\ ^{4}_{2}\alpha$ (**OR** $^{4}_{2}He$)

< atomic number and mass number of α correct > [1]

< atomic number and mass number of Rn correct > [1]

(b) Mass defect :

$\Delta m = 226.0254 - 222.0176 - 4.0026 = 0.0052$ u [1]

Energy released :

$E = 0.0052 \times 931 = 4.84$ MeV [1]

(c) Mass of radium $= 5\ \mu g$

Number of radium atoms in this source :

$N = \frac{5 \times 10^{-6}}{226} \times 6.02 \times 10^{23} = 1.332 \times 10^{16}$ [1]

Decay constant :

$k = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{1600 \times 365 \times 24 \times 3600} = 1.374 \times 10^{-11}\ s^{-1}$ [1]

Activity :

$A = kN = (1.374 \times 10^{-11}) \times (1.332 \times 10^{16}) = 1.83 \times 10^5$ disintegrations per second [1]

< accept 1.83×10^5 Bq > < accept 1.82×10^5 Bq >

12. (a) $\Delta m = 2.014102 + 3.016049 - 4.002602 - 1.008665 = 0.018884$ u [1]

$E = 0.018884 \times 931 = 17.58$ MeV < accept 17.6 MeV > [1]

OR

$E = 0.018884 \times 1.661 \times 10^{-27} \times (3 \times 10^8)^2 = 2.823 \times 10^{-12}$ J [1]

(b) (i) To overcome the electrostatic repulsion between the two (positive) nuclei, [1]

the temperature must be very high so that the ions has sufficient kinetic energy to come close to each other. [1]

(ii) $E_k = \frac{3}{2} \cdot \frac{R}{N_A} \cdot T$

$\therefore (0.2 \times 10^6 \times 1.6 \times 10^{-19}) = \frac{3}{2} \cdot \frac{(8.31)}{(6.02 \times 10^{23})} \cdot T$ [1]

$\therefore T = 1.55 \times 10^9$ K

Order of magnitude of temperature $= 10^9$ K < exact answer not accepted > [1]

13. (a) (i) $x = 3$ 1A | 1

(ii) More neutrons are produced in each fission for triggering further fissions, i.e. $x > 1$. 1A | 1

(b) (i) $m = m_0 e^{-kt}$

$k = \frac{\ln 2}{t_{1/2}}$ $(= 9.846 \times 10^{-10}\ \text{yr}^{-1})$

$0.06 = m_0\, e^{-\ln 2 \times \left[\frac{2 \times 10^9}{7.04 \times 10^8}\right]}$ 1M **OR** $0.06 = m_0 \left(\frac{1}{2}\right)^{2\times10^9 / 7.04\times10^8}$

$m_0 = 0.429882832$ (kg) ≈ 0.430 (kg) 1A | 2

(ii) $\frac{0.430}{13.556 + 0.430} = 0.03073691 \approx 3.1\,\% > 3\%$

Thus natural nuclear fission was possible. 1M/1A | 1

(c) Underground water might run dry. 1A

OR Energy released by fission drys up the underground water. 1A

Therefore, fission might stop without slow neutrons. 1A | 2

Hong Kong Diploma of Secondary Education Examination

Physics – Compulsory part (必修部分)

Section A – Heat and Gases (熱和氣體)
1. Temperature, Heat and Internal energy (溫度、熱和內能)
2. Transfer Processes (熱轉移過程)
3. Change of State (形態的改變)
4. General Gas Law (普適氣體定律)
5. Kinetic Theory (分子運動論)

Section B – Force and Motion (力和運動)
1. Position and Movement (位置和移動)
2. Newton's Laws (牛頓定律)
3. Moment of Force (力矩)
4. Work, Energy and Power (作功、能量和功率)
5. Momentum (動量)
6. Projectile Motion (拋體運動)
7. Circular Motion (圓周運動)
8. Gravitation (引力)

Section C – Wave Motion (波動)
1. Wave Propagation (波的推進)
2. Wave Phenomena (波動現象)
3. Reflection and Refraction of Light (光的反射及折射)
4. Lenses (透鏡)
5. Wave Nature of Light (光的波動特性)
6. Sound (聲音)

Section D – Electricity and Magnetism (電和磁)
1. Electrostatics (靜電學)
2. Electric Circuits (電路)
3. Domestic Electricity (家居用電)
4. Magnetic Field (磁場)
5. Electromagnetic Induction (電磁感應)
6. Alternating Current (交流電)

Section E – Radioactivity and Nuclear Energy (放射現象和核能)
1. Radiation and Radioactivity (輻射和放射現象)
2. Atomic Model (原子模型)
3. Nuclear Energy (核能)

Physics – Elective part (選修部分)

Elective 1 – Astronomy and Space Science (天文學和航天科學)
1. The universe seen in different scales (不同空間標度下的宇宙面貌)
2. Astronomy through history (天文學的發展史)
3. Orbital motions under gravity (重力下的軌道運動)
4. Stars and the universe (恒星和宇宙)

Elective 2 – Atomic World (原子世界)
1. Rutherford's atomic model (盧瑟福原子模型)
2. Photoelectric effect (光電效應)
3. Bohr's atomic model of hydrogen (玻爾的氫原子模型)
4. Particles or waves (粒子或波)
5. Probing into nano scale (窺探納米世界)

Elective 3 – Energy and Use of Energy (能量和能源的使用)
1. Electricity at home (家居用電)
2. Energy efficiency in building (建築的能源效率)
3. Energy efficiency in transportation (運輸業的能源效率)
4. Non-renewable energy sources (不可再生能源)
5. Renewable energy sources (可再生能源)

Elective 4 – Medical Physics (醫學物理學)
1. Making sense of the eye (眼的感官)
2. Making sense of the ear (耳的感官)
3. Medical imaging using non-ionizing radiation (非電離輻射醫學影像學)
4. Medical imaging using ionizing radiation (電離輻射醫學影像學)