GET1024/GEC1036
(Radiation: Scientific Understanding and Public Perception)
AY2021/22 Term Test One
Date: 11 March 2022

Instructions. *This test paper contains 25 questions. It comprises 10 printed pages. Some information which you may need are given on the last page. Answer all questions by shading the best answer in the Answer Sheet. No marks will be deducted for wrong answer. All questions carry equal weightage.*

1. Which of the following statements is true?

   (a) Electromagnetic radiation with longer wavelengths are ionising radiation.

   (b) Neutrons are considered to be ionising radiation because they are very energetic.

   (c) Visible light are considered to be ionising radiation because they can ionise neutral atoms.

   (d) Ionising radiation is generally more harmful to human health compared to non-ionising radiation of the same power.

   (e) Non-ionising radiation can still be harmful because they can cause damage to the DNA.

2. The average annual radiation exposure of a typical person on Earth is about

   (a) 0.000 025 Sv

   (b) 0.000 25 Sv

   (c) 0.002 5 Sv

   (d) 0.025 Sv

   (e) 0.25 Sv

3. The world record of 9.58 s for the 100 m sprint was set by Usain Bolt in 2009. Given that he weighed 94 kg, what is the approximate mass equivalent of his kinetic energy during the sprint?

   (a) 2×10^{-22} kg

   (b) 4×10^{-18} kg

   (c) 6×10^{-14} kg

   (d) 8×10^{-10} kg

   (e) 1×10^{-5} kg

4. de Broglie proposed that because photons have both wave and particle characteristics, perhaps all forms of matter have wave as well as particle properties. In particular he suggested that a particle with momentum p has a wavelength λ associated with it given by h/p where h is the Planck's constant. How has this contributed to the Bohr's model of the atom?

   (a) It explains why there is a very small nucleus in each atom.

   (b) It explains the force acting between the nucleus and the electrons.

   (c) It explains why exist certain specific orbits stated by Bohr could exist.

   (d) It explains why accelerating electrons moving in circular orbits do not radiate electromagnetic energy.

   (e) It explains why electrons have to move in circular orbits around the nucleus.

5. While Bohr's model was very successful in explaining some aspects of the hydrogen spectrum, it fails in many other aspects. Which of the following are areas which the Bohr's model fail?

   1. Unable to explain why some some spectral lines are brighter than other lines
   2. Unable to explain the fine structure observed in hydrogen and other atoms.
   3. Unable to explain the other series of the hydrogen spectrum except the Balmer series, e.g., Lyman and Paschen series.
   4. Unable to calculate the spectrum of most other atoms.

   (a) 1 and 3 only

   (b) 2 and 4 only

   (c) 1, 2 and 3 only

   (d) 2, 3 and 4 only

   (e) 1, 2 and 4 only

6. Comparing the size of an atom to its nucleus, if we imagine the Earth of radius $\approx 6,370$ km to be the atom, say gold or uranium atom, what would most represent the nucleus (just compare the dimensions only and not worry about the shape)?

   (a) Core of Halley's comet (≈ 10 km)

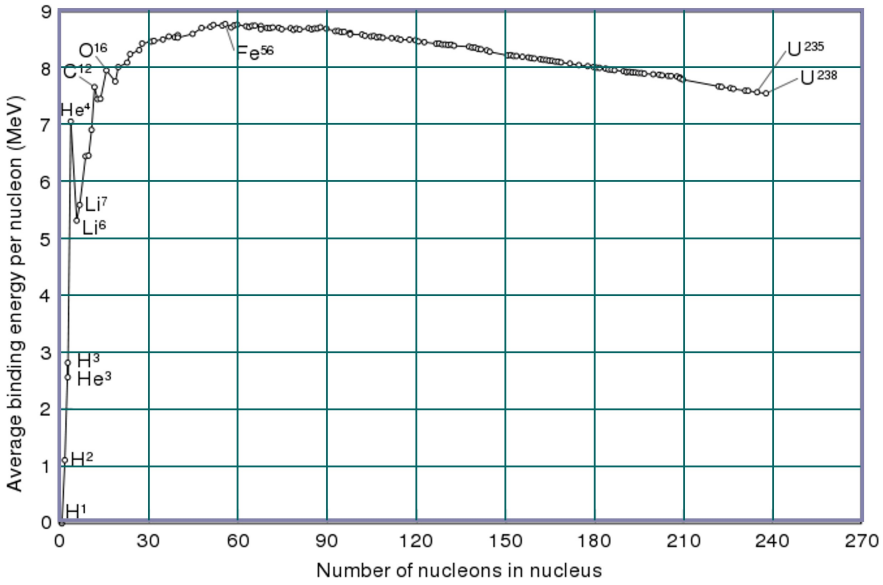
   (b) NUS Kent Ridge campus (≈ 1 km)

   (c) International Space Station (≈ 100 m).

   (d) Vacuum chamber of ITER Tokamak (≈ 10 m)

   (e) Human body (≈ 1 m)

7. Based on the graph of binding energy per nucleons vs number of nucleon in nucleus given below, which of the following statements is true?



(a) We need about 7 MeV to split up He^4 to its constituent nucleons.

(b) It requires more energy to split up He^4 to its constituent nucleons than to split Li^7.

(c) It requires more energy to split up Fe^{56} to its constituent nucleons than to split U^{238}.

(d) There would be energy release if three He^4 nuclei fuse to form one C^{12} nuclei.

(e) Net energy is needed to fuse He^4 with C^{12} to form O^{16}.

8. α, β and γ radiations are the most common types of radiation from radioactive sources. Which of the following statements is incorrect.

(a) α radiation is less penetrating than β or γ radiation.

(b) β radiation can be stopped by lead plates.

(c) The trajectories of all three types of radiation are affected magnetic field.

(d) β particles generally move faster than α particles.

(e) The kinetic energy of β particles exhibits a continuous spectrum.

9. A uranium pellet that is used in nuclear reactor has a mass of 10 g. Assuming that its main compound is uranium dioxide (UO_2) and it is enriched with 4% of U-235, what is the activity of this pellet? Half-lives of $^{235}_{92}$U and $^{238}_{92}$U are 7.04×10^8 years and 4.47×10^9 years respectively. The atomic mass of oxygen is 16.0 u.

   (a) 1.09×10^5 Bq

   (b) 1.33×10^5 Bq

   (c) 1.51×10^5 Bq

   (d) 1.75×10^5 Bq

   (e) 1.93×10^5 Bq

10. Consider the following radioactive sources:

    1. 10 g of $^{14}_{6}$C with half-life of 5700 years
    2. 2.0 kg of $^{238}_{92}$U with half-life of 4.5 billion years
    3. 0.10 g of $^{137}_{55}$Cs with half-life of 30.0 years
    4. 20 mg of $^{3}_{1}$H with half-life of 12.3 years

    Which of the following sequences correctly rank the activities of these sources (from the highest to the lowest)?

    (a) 4, 1, 3, 2

    (b) 2, 4, 1, 3

    (c) 3, 1, 4, 2

    (d) 1, 4, 3, 2

    (e) 2, 1, 4, 3

11. A scientist at a nuclear facility suspects that the bowl of microwaved soup that he ate was spiked with a water soluble radioactive substance. Which of the following statements is correct?

    (a) Measuring his radioactivity using a full body gamma spectrometer will prove if he had ingested a radioactive substance.

    (b) Determining the amount of radiation he had been exposed to by analysing his personal electronic dosimeter readings will prove if he had ingested a radioactive substance.

    (c) Analysing his urine over the next few days using a gamma spectrometer will prove if he had ingested a radioactive substance.

    (d) Analysing his poop over the next few days using a mass spectrometer will prove if he had ingested a radioactive substance.

    (e) Microwaving the soup caused the soup to become radioactive.

12. A scientist was working with a 1 cm^3 radioactive solid sample that was known to only decay through alpha decay. The scientist is only wearing latex gloves for personal protection. Given that the activity of this sample is 10 Gy per hour, and that the radiation weighting factor WR for alpha particles is 20, which of the following statements is correct?

    (a) His absorbed dose rate is roughly 10 Gy per hour.

    (b) His absorbed dose rate is roughly 200 Gy per hour.

    (c) His effective dose rate is roughly 10 Sv per hour.

    (d) His effective dose rate is roughly 200 Sv per hour.

    (e) None of the statements are correct.

13. It was suspected that a man was accidentally exposed to radiation from a radioactive source that is placed inside an instrument. Which of the following information would not help in determining the amount of radiation that he was exposed to?

    (a) The identity of the radioactive element.

    (b) The water solubility of the radioactive element present.

    (c) The distance of the radioactive source from the man.

    (d) The mass of the radioactive element present.

    (e) The length of the exposure.

14. When discussing the general public's everyday radiation exposure, the units of Grays (Gy) and Sieverts (Sv) are often used interchangeably. What is the most likely reason for this?

    (a) Because Gy and Sv are both in Joules per kilogram.

    (b) Because the general public will almost never come across anything that contains alpha decaying radioactive nuclides in everyday life.

    (c) Because everyday radiation exposure is mostly caused by highly penetrating radiation that has a radiation weighting factor of 1.

    (d) Because the amount of everyday radiation exposure is so insignificantly small, the units do not matter.

    (e) None of the above statements are correct.

15. A man picked up an expensive looking object on the street and spent the day with the object in his pocket. It turns out the object was a highly radioactive gamma source. Doctors were tasked with determining the dose that he received. Which of the following would be useful for this purpose?

    (a) Take the fabric of this pocket and analyse it with a gamma spectrometer.

    (b) Cut out some of his tissue that was nearest to the source and analyse it with a gamma spectrometer.

    (c) Analyse the man using a full body gamma spectrometer.

    (d) a, b and c would be all helpful.

    (e) None of them would be helpful.

16. In a typical HDB bedroom cooled by air-conditioner during the night, we expect the level of radon to be highest in the early morning because

    (a) more radon is formed at lower temperature.

    (b) more radon is formed during low light conditions.

    (c) heat during the day helps to convert radon to other gases.

    (d) radon coming out from walls is not circulated out of the room during the night.

    (e) radon is transferred by the air-conditioner to the bedroom when it is turned on during the night.

17. Which of the following statements on cosmic rays is incorrect?

    (a) The radiation that reaches the Earth surface are mainly secondary cosmic rays.

    (b) The primary cosmic rays coming from space consist mainly of exotic particles such as muons and pions.

    (c) We are subjected to much higher radiation from cosmic rays when we fly at higher altitude.

    (d) We are subjected to much higher radiation from cosmic rays when we fly at higher latitudes.

    (e) The typical annual dose due to cosmic rays for a person living in a region near sea level is about 0.3 mSv.

18. Thorium dioxide has been used in camera lenses in the past because

    (a) thorium is plentiful and relatively cheap.

    (b) thorium dioxide is more transparent than most other materials used for lens.

    (c) thorium dioxide has high refractive index and low dispersion.

    (d) thorium dioxide is easier to be manufactured and ground to the right curvature.

    (e) thorium dioxide is strong, hard and does not crack easily.

Questions 19 and 20 are based on the table of the half value layer (HVL) of various materials for gamma ray of energies 100 keV, 200 keV and 500 keV. The price and density of aluminium, iron, copper and lead are also given.

	Half Value Layer (cm)				
Absorber	**100 keV**	**200 keV**	**500 keV**	**Price per kg (US$)**	**Density (g/cm^3)**
Air	3555	4359	6189		
Water	4.15	5.1	7.15		
Carbon	2.07	2.53	3.54		
Aluminium	1.59	2.14	3.05	3.4	2.7
Iron	0.26	0.64	1.06	1.6	7.87
Copper	0.18	0.53	0.95	10.1	8.94
Lead	0.012	0.068	0.42	2.4	11.34

19. The dose rate outside a room housing a radioactive source emitting gamma rays of energy in the range of 300 keV to 500 keV when it is operating is 16 μSv/h. To reduce it to the level within regulation of 0.5 μSv/h, what would you recommend to be added to the wall of the room, taking into account any other factors given in the table above?

    (a) 10 cm of aluminium

    (b) 5 cm of copper

    (c) 3 cm of iron

    (d) 2 cm of lead

    (e) 10 cm of lead

20. The other concern is the door of the room. Assuming that we need to reduce the dose rate outside the door by a factor of 16, what would be estimated weight added to the door if we line it with lead? The door has a dimension of 2.0 m by 1.5 m.

    (a) 23 kg

    (b) 102 kg

    (c) 570 kg

    (d) 1710 kg

    (e) 4300 kg

21. Which of the following statements is **NOT** true regarding factors that affect the extent of biological responses to radiation exposure?

    (a) A fractionated dose delivered over a period of many months is likely to be less detrimental compared to a single, acute dose of the same amount.

    (b) A younger person will always have a lower risk of developing cancer as a result of radiation exposure because they are generally healthier.

    (c) Younger cells have more anti-oxidant mechanisms and are therefore less susceptible to reactive oxygen species generated by radiation exposure.

    (d) Alpha particles are less hazardous when the exposure is external compared to when the exposure is internal, because it has a low penetration depth compared to other types of radiation

    (e) Cells with higher mitotic activity are more radiosensitive. This is why the bone marrow and reproductive organs are the most susceptible.

22. Which of the following statements is true?

    (a) Deterministic effects occur once a threshold of exposure has been reached, and the severity decreases as dose increases.

    (b) Deterministic effects are generally a result of accumulation of mutations in the cell.

    (c) The severity of stochastic effects are not dose related.

    (d) Stochastic effects are generally a result of cell death.

    (e) Deterministic effects are believed to follow a linear no-threshold model.

23. Person A and Person B each receive a mean absorbed dose of 0.2 mGy to the lungs due to inhalation of α particles. Assume the tissue weighting factor for the lungs is 0.12. Which of the following is true:

    1. The effective dose received by person A is 0.48 mSv
    2. Assuming the tissue weighting factor for the skin is 0.01, Person C receiving the same absorbed dose of gamma radiation to the skin will have received an effective dose that is 12 times less than Person C.
    3. If Person C is younger than Person A, Person C will have received a lower effective dose than Person A.

    (a) 1 only

    (b) 1 and 2 only

    (c) 1 and 3 only

    (d) 2 and 3 only

    (e) 1, 2 and 3 only

24. Which of the following is true regarding the various methods of studying the biological effects of radiation?

    1. Epidemiological studies can be susceptible to many confounding factors that may make the correlation between radiation exposure and biological effects difficult.
    2. Studying the biological effects using human-derived cells ex vivo will accurately reflect the whole body physiological response in humans.
    3. Only studies on human populations can be used to study physiological effects.
    4. Plants cannot be used to study biological effects of radiation as they are not affected by radiation exposure.

    (a) 1 only
    (b) 2 only
    (c) 1 and 3 only
    (d) 1, 2 and 3 only
    (e) 1, 2, 3 and 4

25. A person accidentally ingested a radioactive substance. Which of the following could potentially serve as a means for therapy:

    1. Administration of a compound which prevents the radioactive substance from binding to target organs
    2. Administration of a compound which halts blood cell production in the bone marrow
    3. A skin cell transplant
    4. Administration of a free radical scavenger

    (a) 1 only
    (b) 2 only
    (c) 4 only
    (d) 1 and 4 only
    (e) 1, 3 and 4 only

— End of Paper —

TABLE OF INFORMATION

You may or may not use any of the information given here.

Speed of light in vacuum, c	=	2.998×10^{8} m/s		
Charge of electron, e	=	1.602×10^{-19} C		
Planck's constant, h	=	6.626×10^{-34} J $\cdot$ s		
Boltzmann constant, k	=	1.381×10^{-23} J/K		
Avogadro's number, N_A	=	6.022×10^{23} mol^{-1}		
Atomic mass unit, u	=	$1.660\,539\,1 \times 10^{-27}$ kg	=	931.494 10 MeV/c^2
Mass of electron, m_{e}	=	$9.109\,389\,7 \times 10^{-31}$ kg	=	0.510 999 06 MeV/c^2
Mass of proton, m_{p}	=	$1.673\,532\,9 \times 10^{-27}$ kg	=	938.272 09 MeV/c^2
Mass of neutron, m_{n}	=	$1.674\,927\,5 \times 10^{-27}$ kg	=	939.565 42 MeV/c^2
Mass of hydrogen, m_{H}	=	$1.674\,928\,6 \times 10^{-27}$ kg	=	938.783 08 MeV/c^2