a) Task 1: Explaining trend in melting points of the metal chlorides.

The melting points of the metal chlorides decrease in the order:
$NaCl > MgCl_2 > AlCl_3$ even when they all have giant ionic structures.
This is due to increasing Polarizing power of the metal cation and hence increasing Covalent Character in the ionic bond between the metal cation and the chloride ion, as the size of the cation decreases from Na^+ to Al^{3+} and ionic charge increases from Na^+ to Al^{3+}.
Sodium chloride ($NaCl$) has predominantly ionic bonding with the strongest electrostatic attraction between Na^+ ions and chloride ions (Cl^-) giving sodium chloride the highest melting point.
The magnesium ion, Mg^{2+}, has a greater charge density and hence greater polarizing power than the sodium ion, Na^+, thus polarizes the chloride ions more strongly making $MgCl_2$ have greater covalent character hence lower melting points.

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The aluminium ion, Al^{3+}, being the smallest with highest ionic charge, has the highest charge density and highest polarizing power. Thus polarizes the chloride ion, the most causing $AlCl_3$ to become predominantly covalent, reducing its effective ionic character such that it has the weakest ionic bond and lattice, hence the lowest melting point.

b) Task 2: Justifying the most suitable extraction method for Sodium, Magnesium and Aluminium

The appropriate extraction method depends mainly on the position of the metal in the reactivity series.

i) Sodium metal is very reactive and cannot be obtained by reducing Na^+ with carbon or even by electrolysis of aqueous solutions of its salts due to preferential discharge of water. It is therefore extracted by electrolysis of molten rock salt, (NaCl)

$$2NaCl(l) \longrightarrow 2Na(l) + Cl_2(g)$$

ii) Magnesium metal is also highly reactive and is best extracted by electrolysis of molten magnesium chloride since the Mg^{2+} ions cannot be reduced by carbon

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Aqueous magnesium chloride is also not used because water would undergo preferential reduction at the cathode producing hydrogen gas instead of magnesium metal.

$MgCl_{2(l)} \longrightarrow Mg_{(l)} + Cl_{2(g)}$ CI

ii) Aluminium metal cannot be extracted by direct electrolysis of the molten or aqueous aluminium chloride

This is because the aluminium ion, Al^{3+} are not preferred for discharge to hydrogen ions, H^+, at the cathode in aqueous state.

Also direct use of anhydrous aluminium chloride is not possible because of its high covalent character, hence ability to sublime rather than melt.

Al is therefore extracted by electrolysis of molten aluminium oxide dissolved in molten cryolite.

$2Al_2O_{3(l)} \longrightarrow 4Al_{(l)} + 3O_{2(g)}$ CI Cm

8 Cr + 3 Cm + 3 CI = 0

c) Task 3: Reaction of aluminium chloride with water, and accounting for all observations

Aluminium chloride, readily hydrolyses in water producing hydrochloric acid. The hydration of the aluminium ions, Al^{3+} or hydrolysis of aluminium chloride, $AlCl_3$ is highly exothermic which makes the reaction vigorous.

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The misty white fumes are due to the hydrogen chloride produced reacting with moisture in the air to form fine droplets of hydrochloric acid appearing as misty white fumes.

$$AlCl_{3(s)} + 3H_2O_{(l)} \longrightarrow Al(OH)_{3(s)} + 3HCl_{(g)or(aq)}$$

The strongly acid solution is due to the hydrochloric acid formed or due to hydrolysis of the hydrated aluminium ion, $[Al(H_2O)_6]^{3+}$, that produces hydrogen ions or hydroxonium ions that make the solution strongly acidic.

$$[Al(H_2O)_6]^{3+}_{(aq)} + H_2O_{(l)} \rightleftharpoons [Al(H_2O)_5OH]^{2+}_{(aq)} + H_3O^+_{(aq)}$$

2Ec + 8Cr = 04

d) Task 4): Explaining reactions of the acidic solution of $AlCl_3$ with Magnesium metal and sodium carbonate

i) Magnesium metal and the acidic solution of aluminium chloride undergo a redox reaction in which magnesium is oxidized to magnesium ions, Mg^{2+}, while hydrogen ions (or hydroxonium ions) are reduced to hydrogen gas which is seen as effervescence of a colourless gas, but no white precipitate is formed.

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$Mg_{(s)} + 2H^+_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + H_{2(g)}$ E

OR $Mg_{(s)} + 2H_3O^+_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + H_{2(g)} + 2H_2O_{(l)}$ E

Sodium carbonate undergoes a neutralization Rt reaction with the acidic solution of aluminium chloride producing carbon dioxide gas Cr seen as effervescence of a colourless and odourless gas and insoluble aluminium hydroxide Cr seen as the white precipitate.

$2AlCl_{3(aq)} + 3Na_2CO_{3(s)} + 3H_2O_{(l)} \longrightarrow 2Al(OH)_{3(s)} + 3CO_{2(g)} + 6NaCl_{(aq)}$ E.

OR $2[Al(H_2O)_6]^{3+}_{(aq)} + CO_3^{2-}{}_{(s)} \longrightarrow 2[Al(OH)_3(H_2O)_3]_{(s)} + 3CO_{2(g)} + 3H_2O_{(l)}$ E

OR $2Al^{3+}_{(aq)} + 3CO_3^{2-}{}_{(aq)} + 3H_2O_{(l)} \longrightarrow 2Al(OH)_{3(s)} + 3CO_{2(g)}$ E

2E + 2Rt + 4Cr = 05

(c) Task 5: Explaining application of hydrogen chloride industrially in preparing NaCl and $AlCl_3$.

i) Hydrogen formation of sodium chloride, NaCl

Hydrogen chloride is neutralized Rt with either sodium hydroxide or sodium carbonate to form sodium chloride Cr which is then

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Concentrated Cd and crystallized Cd to obtain sodium chloride crystals.

$NaOH_{(aq)} + HCl_{(g)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$ ✓E

OR ✓E. $2HCl_{(aq)} + Na_2CO_{3(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

ii) Formation of Iron(II) chloride.

In this case hydrogen chloride is first dissolved in water to form hydrochloric acid. Iron is then oxidized by the hydrochloric acid in a redox reaction where hydrogen chloride is reduced to hydrogen gas and iron oxidized to iron(II) ions.

$Fe_{(s)} + 2HCl_{(aq)} \longrightarrow FeCl_{2(aq)} + H_{2(g)}$

The iron(II) chloride is then concentrated and crystallized to obtain iron(II) chloride crystals.

$2Rt + 4Cd + Pr + 3Cr = 04$

b) Task 6: Uses of NaCl and $FeCl_2$ industrially.

Sodium chloride is used in the manufacture of chlorine, sodium hydroxide and hydrogen by electrolysis of brine or concentrated solution of the salt, since it is an inexpensive source of sodium ions, and chloride ions. 02

Iron(II) chloride is used in wastewater treatment, sludge dewatering and odour control. This is because iron(II) ions, Fe^{2+} promote coagulation and precipation of unwanted substances in water and it also a reducing agent. TOTAL = 25 SCORES $2Fe + Es = 02$

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ITEM 4

Possible responses.

a) Task 1: Explaining oxidation of Calcium and alpha decay of Uranium-238.

i) Oxidation of Calcium by oxygen.

Calcium and oxygen undergo a redox reaction in which Calcium is oxidized to Calcium ions by losing two valence electrons Rt Cr

$Ca_{(s)} \longrightarrow Ca^{2+}_{(g)} + 2e^-$ CI

At the same time oxygen atoms gain the electrons donated by calcium getting reduced Cr to oxide ions

$O_{(g)} + 2e^- \longrightarrow O^{2-}_{(g)}$ CI

or $O_{2(g)} + 4e^- \longrightarrow 2O^{2-}_{(g)}$ Cr

The Calcium ions then attract the oxide ions to form strong ionic bonds in calcium oxide

$Ca^{2+}_{(g)} + O^{2-}_{(g)} \longrightarrow CaO_{(s)}$ E

Although calcium loses its valence electrons, its nucleus remains unchanged because the proton number remains unchanged (or 20 protons), hence the element remains Calcium. Cr

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i) Alpha decay of Uranium-238

When Uranium-238 undergoes alpha decay its mass number reduces by four while its proton number (or atomic number) reduces by two due to loss of an alpha particle that has two protons and two neutrons. Therefore, the uranium nucleus changes into a new nucleus of a new element thronium-234. with different proton number (90).

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

$2R_t + 2E + 2C_I + 8C_r = 05$

b) Task 2: Analysis of data by graphical method.

Original: Draw graph

By Graphical method:

Original quantity of the radioactive material present = 100g

Estimating half life:

$$t_{\frac{1}{2}} = \frac{(39.2 + 39.1) \times 10^{12}}{2}$$

$= 39.2 \times 10^{12}$ hrs (OR 3.92×10^{13} hrs)

OR 39.15×10^{12} hrs.

$2V_c + 5C_A = 07$

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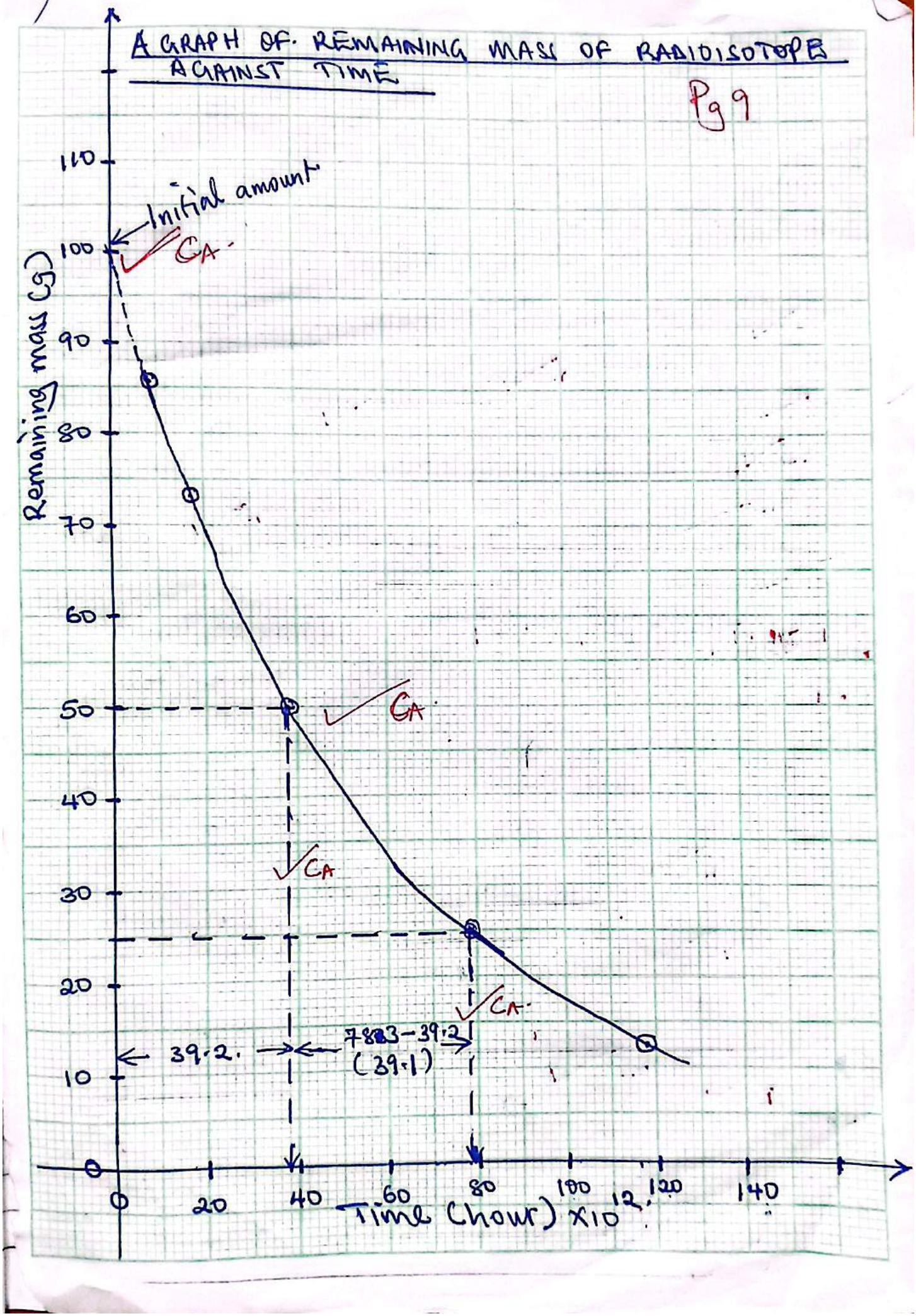
A GRAPH OF REMAINING MASS OF RADIOISOTOPE AGAINST TIME
Pg 9
Remaining mass (g)
110
100
90
80
70
60
50
40
30
20
10
0
Initial amount
CA
CA
CA
CA
39.2
78.3 - 39.2
(39.1)
0
20
40
60
80
100
120
140
Time (hour) X10^12

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(Alternative)

Method 2 (using data directly by observation)

i) Determining original amount

At time $t_1 = 39.2 \times 10^{12}$ hrs, the remaining mass is 50.00g. ✓CA

At time $t_2 = 78.3 \times 10^{12}$ hrs, the remaining mass is 25.00g which is ½ of 50.00g. ✓CA

Thus 50.00g is ½ of 100g ✓CA ✓Vc

Hence, initial amount was 100g.

ii) Determining half-life

From table.

From 50.00g to 25.00g

$t_{\frac{1}{2}} = (78.3 - 39.2) \times 10^{12}$ ✓CA

$= 39.1 \times 10^{12}$ hrs. ✓CA

From 25.00g to 12.50g another half.

$t_{\frac{1}{2}} = (117.5 - 78.3) \times 10^{12}$ ✓CA

$= 39.2 \times 10^{12}$ hrs. ✓CA

Thus half-life is approximately

$= \frac{(39.1 + 39.2) \times 10^{12}}{2}$ ✓CA

$= 39.2 \times 10^{12}$ hrs. ✓Vc

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c) Task 3: Explanation of changes during alpha decay.

During alpha decay, an alpha particle equivalent to a helium atom (${}^{4}_{2}He$) is emitted. This lead to loss of two protons and two neutrons from the parent nuclide such that the atomic number decreases by two (2) while the mass number decreases by four (4) forming a new element.

$$ {}^{M}_{A}X \longrightarrow {}^{(M-4)}_{(A-2)}| + {}^{4}_{2}He $$

$4Ce + C_I = 0$

d) Task 4: Evaluating chemical and nuclear reactions.

i) Similarities

- Both reactions involve change in matter
- Both reactions involve loss or absorption of energy (or radiation)
- Both reactions obey conservation laws or principles.
- Both reaction produce new products
- Both reactions can occur naturally or artificially.

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ii) Differences between chemical and nuclear reactions.

Chemical reactions	Nuclear reactions
✗ Involve only valency electrons.	✓ Involves the nucleus
✗ No new element formed	✓ New element is formed
✗ Small energy changes occur	✓ Very large energy changes occur.
✗ Influenced by external factors such as temperature and pressure and catalysts	✓ Not affected by temperature Pressure or catalysts.
✗ Atomic number remains unchanged	✓ Atomic number is changed.
✗ Usually produces new compounds or ions	✓ Can produce a different element or isotope.

4 Es + 4 Ed = 08

(2-3) Es + (2-3) Ed = 03

e) Task 5: Contributions / Applications of radioactivity to modern society.

i) Gamma radiation from Cobalt-60 are used in radiotherapy to treat cancer or destroy cancer cells.

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ii) Gamma radiation from radio isotopes (such as Technetium-99m) are used in detecting and imaging organs such as the heart, bones, and kidneys in medical diagnosis. SB

iii) Radiations from iodine-131 can be used used to destroy abnormal thyroid tissue during treatment of thyroid disorders. SB

iv) Beta radiation from Strontium-90 can be used to monitor the thickness of materials such as iron sheets, plastics during manufacture.

v) Gamma rays from Cobalt-60 are used to detect internal defects in metals, welds. 04

vi) Gamma radiation from Cobalt-60 can sterilize insects so that males are sterile and cannot reproduce anymore, hence Controlling Pests.

vii) Alpha particles emitted by Americium-241 help in fire detection when they ionize air inside some smoke detectors. Once smoke disrupts the ionization, it triggers the alarm.

viii) Carbon-14 is used to estimate the age of once-living materials by measuring radioactive decay.

SB = 8/8

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e) Task 6: Risks associated with exposure to radioactive radiation and mitigation measures

Hazards / Risks	Mitigation
i) Radioactive radiations are highly ionizing Di and thus damage DNA and other cell molecules causing cell death, De mutations and increased risk to Cancer.	By minimizing exposure time, maximizing distance from the source or using suitable shielding and monitoring radiation dose. Dm
ii) Alpha particles have very high ionizing power De but low penetrating power. Thus when inhaled, swallowed or enter wounds can cause intense De ionization of nearby tissues and cell damage.	By preventing radioactive material from entering the body by using appropriate protective equipment and through monitoring alpha particle contamination. Dm
iii) Beta particles have moderate penetrating power and moderate ionizing power. De Therefore, when they penetrate the skin they irradiate De underlying tissue causing skin damage and cell mutations	By minimizing exposure time, increasing distance of source and using appropriate shielding and protective procedures Dm

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Answer Sheet

Scores grid (For Examiner's use only)

ITEM						TOTAL
SCORE						

TOTAL SCORE	Pg 15

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iv) Gamma rays have very high penetrating power. This can pass deeply through the body and expose internal organs causing DNA and tissue damage and increased cancer risk.

By using adequate shielding such as Lead sheets or Concrete and, maximizing distance to the source and minimizing exposure time. Dm

v) Some radioactive materials have long half-lives such that they remain radioactive for long periods creating a persistent exposure and contamination that may cause prolonged biological effects

By restricting access, monitoring contaminated areas, clearly labeling sources to ensure proper radioactive-waste disposal. Dm

vi) Some radioactive materials can enter and remain within the body irradiating organs as it decays causing prolonged tissue damage and increased cancer risks.

By preventing inhalation and ingestion through Contaminated foods, water and storage. Dm

TOTAL 25 SCORES

3Di + 3De + 3Dm = 04

2Di + 2De + 2Dm = 02