1. I-131 destroys the thyroid follicular cells by what particulate emission during its radioactive decay?
   A. Alpha
   B. Beta
   C. Gamma
   D. Positron

2. What is the half-life of I-131?
   A. 13 hours
   B. 2.8 days
   C. 3.2 days
   D. 8.1 days
   E. 13.2 days

3. The following histogram is generated by what radionuclide?
   A. I-131
   B. In-111
   C. I-123
   D. Tc-99m
   E. TI-201
4. You have 30 mCi of I-123 remaining in the radiopharmacy. A patient is scheduled to have an I-123 scintigraphy approximately 2 days from now. How much I-123 would remain at the time of the scheduled examination?
   A. 25.3 mCi
   B. 18.9 mCi
   C. 8.3 mCi
   D. 2.3 mCi
   E. 1.2 mCi
   F. 0.646 mCi

5. Which of the following radiopharmaceuticals is trapped by the thyroid follicular cells but NOT organified?
   A. Tc-99m pertechnetate
   B. I-123 sodium iodide
   C. I-131 MIBG
   D. In-111 pentetreotide
   E. Tc-99m sestamibi

6. The instrument shown below is a scintillation probe, which is commonly used to calculate the radioiodine uptake by the thyroid gland. Which of the following instruments is most closely related to the scintillation probe?
   A. Geiger-Mueller counter
   B. Ionization chamber
   C. Well counter
   D. Dose calibrator
A 67-year-old gentleman received 101 mCi of I-131 sodium iodide for the treatment of his differentiated thyroid carcinoma. Which of the following instruments would be typically used to measure the radioactivity emanating from the patient prior to his release?

The following Tc-99m pertechnetate thyroid scintigraphy image is from a 25-year-old female with hyperthyroidism. What is the most likely 24-hour I-123 radioiodine uptake (RAIU) value for this patient?

A. 5%
B. 15%
C. 30%
D. 60%
9. What type of collimator is typically used to acquire I-123 thyroid scintigraphy images?
   A. Low energy high resolution (LEHR)
   B. Medium energy
   C. High energy
   D. Pin hole

10a. The following image is from a 21-year-old female with recent history of viral upper respiratory infection who presents with the complaints of palpitations and tremor. Which of the following is the most likely diagnosis?
   A. Plummer disease
   B. Subacute thyroiditis
   C. Graves disease
   D. Acute suppurative thyroiditis
   E. Primary hypothyroidism

10b. What is the cause of hyperthyroidism in these patients?
   A. Increased thyroid-stimulating immunoglobulins
   B. Increased thyroid hormone production
   C. Increased TSH secretion by the pituitary
   D. Release of preformed thyroid hormone
   E. Antithyroid peroxidase antibodies

11. Which of the following symptoms would be MOST helpful in establishing the correct diagnosis of subacute granulomatous thyroiditis, also known as de Quervain thyroiditis?
   A. Painful thyroid on palpation
   B. Nonpalpable thyroid
   C. Nodular thyroid gland
   D. Proptosis
   E. Tachycardia
12. What is the most appropriate I-131 dose to treat the patients with Graves disease?
A. 1 to 4 mCi
B. 5 to 20 mCi
C. 30 to 100 mCi
D. 101 to 200 mCi

13. What is the most appropriate I-131 dose to treat patients with this condition?

14. Which of the following disease process results in increased radioiodine uptake by the thyroid gland?
A. Viral thyroiditis
B. Iodine deficiency-induced hypothyroidism
C. Jod-Basedow phenomenon
D. Factitious hyperthyroidism

15. How long after administration of I-131 radioiodine can the patient resume breast-feeding?
A. 8 days
B. 80 days
C. 8 months
D. Next pregnancy

16. How long after administration of I-123 radioiodine can the patient resume breast-feeding?
A. 24 hours
B. 48 hours
C. 8 days
D. Next pregnancy
**Answers and Explanations**

1. **Answer B.** Iodine-131 (I-131) undergoes beta minus decay and emits a primary gamma photon of 364 keV as well as high-energy beta particles. Beta particles travel substantial distances in air, but only travel a few millimeters in tissue before getting absorbed. High radiation absorbed dose from beta particle emission combined with a long physical and biologic half-life of I-131 in the thyroid results in gradual destruction of the thyroid follicular cells. Gamma and positrons are photons and not particles.


2. **Answer D.** I-131 has a half-life of 8.1 days.


3. **Answer C.** Iodine-123 (I-123) decays by electron capture and emits a primary gamma photon of 159 keV. No particulate emission (alpha or beta) combined with relatively short half-life results in low radiation absorbed dose to the thyroid gland. Also, the primary gamma photon of 159 keV is well suited for imaging using the modern gamma cameras.


4. **Answer D.** Iodine-123 has a half-life of 13 hours. Two days (48 hours) is slightly less than four half-lives of 52 hours. So the remaining activity would be slightly more than the residual activity of 1.8 mCi at 52 hours, making 2.3 mCi as the correct answer. Alternatively, this can be accurately calculated using the following formula:

   \[
   A = A_0 \times e^{-0.693 \cdot \text{half-life} \cdot t}
   \]

   \[A = \text{remaining activity} ; \quad A_0 = \text{activity at time 0} ; \quad t = \text{time of decay}\]


5. **Answer A.** “Trapping” refers to the intracellular concentration of a substance by the sodium–iodine symporter located on the cell membrane of the thyroid follicular cells. “Organification” refers to oxidation, iodination, and coupling of iodine to the tyrosine residues on thyroglobulin by the thyroid peroxidase enzymes. Tc-99m pertechnetate undergoes trapping without organification. As such, it can gradually wash out of the thyroid gland, requiring imaging at 20 minutes after IV administration. On the other hand, I-123 and I-131 are organified into T3 and T4 and stored in the colloid-filled follicular lumen. Antithyroid medication such as propylthiouracil and methimazole block this organification process.


6. **Answer C.** Scintillation probes, well counters, and gamma cameras utilize crystal-based scintillation detectors (NaI, CdZnTe, etc.) coupled to a photomultiplier tube for radiation detection. Radiation from the radiopharmaceuticals generates light pulses in the crystal, which are then converted into a voltage signals by the
photomultiplier tube (PMT). A scintillation probe used for thyroid uptake utilizes a thick (5-cm) NaI crystal coupled to a PMT. A well counter uses a similar crystal with a well cut into the center of the crystal where a sample may be placed; it is a highly sensitive device used to detect a very small amount of radioactivity (up to 1 mCi) such as those of wipe tests or in vitro studies (GFR, shillings test, etc.).

Geiger-Müller (GM) counters, ionization chambers, and dose calibrators employ detectors with gas-filled chambers. Radiation from the radiopharmaceuticals interacts with the gas, causing ionization and generating an electric signal. A GM survey meter is used to detect low levels of radiation, while ionization survey chamber can be used to detect and quantify higher levels of radiation. A dose calibrator is a well-type ionization chamber used to accurately measure the radiopharmaceutical doses (activities) given to the patients.


7 Answer B. Ionization chambers (image B) are typically used to measure high exposure rates (range from 0.1 mR to 100 R) such as those from the patients receiving radioiodine therapy for cancer. If the patient receives more than 33 mCi of I-131 on an outpatient basis, then precautions are taken to ensure that no other person would receive more than 500 mrem (5 mSv) from exposure to the released patient. Activity is measured at 1 m and 3 m using an ionization chamber, and values are typically entered into a spreadsheet to generate a list of precautions to be discussed with the patient and the family members. Geiger-Müller counters (image A) are very sensitive and are used to detect a very small amount of radioactivity (i.e., contamination). Gamma camera (image C) and scintillation probe (image D) are used for scintigraphy and radioiodine uptake measurement, respectively.


8 Answer D. The 20-minute anterior image obtained after IV administration of 10.9 mCi of Tc-99m pertechnetate demonstrates enlarged thyroid gland with convex borders. A linear focus of activity extending superiorly from the left isthmus is the pyramidal lobe. The absence of significant background activity and lack of visualization of the physiologic uptake in the salivary glands imply marked increase in the radiopharmaceutical uptake. The findings are those of Graves disease. The Graves disease is caused by increased levels of thyroid-stimulating immunoglobulins (TSI), which cause marked overstimulation of the thyroid follicular cells. The typical 24-hour RAIU in these patients ranges from 50% to 80%. In comparison, the 24-hour RAIU in multinodular goiter and toxic autonomously functioning nodule ranges from 20% to 30% (upper limits of normal to mildly elevated). Normal %RAIU is 4% to 15% at 4 to 6 hours and 10% to 30% at 24 hours.


9 Answer D. Pinhole collimator is typically used for imaging the thyroid gland. The resultant magnification provides superior resolution compared to the parallel hole collimator.

**10a Answer B.** Absent or poor visualization of thyroid gland and decreased RAIU are seen with primary or secondary hypothyroidism, thyroid gland destruction (acute phase of subacute thyroiditis, type II amiodarone toxicity), exposure to excess iodine (iodinated contrast, or type I amiodarone toxicity), or suppression of thyroid from excess exogenous thyroid hormone (struma ovarii or factitious hyperthyroidism). In this patient with clinical history of recent URI and symptoms of hyperthyroidism, the diagnosis is subacute thyroiditis, specifically subacute granulomatous thyroiditis.

Acute suppurative thyroiditis is an extremely rare but potentially life-threatening bacterial infection; patients present with anterior neck swelling, pain, and fever. However, it typically does not result in significant hyperthyroidism. Plummer disease and Graves disease result in hyperthyroidism but demonstrate increased radioiodine uptake.


**10b Answer D.** Subacute thyroiditis occurs secondary to the destruction of the thyroid follicular cells, which results in the spillage of preformed thyroid hormone into the bloodstream. Three forms of subacute thyroiditis are recognized: subacute granulomatous thyroiditis (aka painful or de Quervain thyroiditis), subacute lymphocytic thyroiditis (aka painless thyroiditis), and subacute postpartum thyroiditis. Increased thyroid-stimulating immunoglobulins (TSI) are seen with Graves disease. Antithyroid peroxidase antibodies are typically seen with Hashimoto’s thyroiditis.


**11 Answer A.** The specific diagnosis in patients with absent or markedly decreased radioiodine uptake and hyperthyroidism depends on their clinical presentation. Specific clinical inquiries regarding recent URI infection and neck pain, recent exposure to iodinated contrast, postpartum status, and amiodarone treatment would help establish a specific diagnosis of subacute granulomatous thyroiditis, Jod-Basedow syndrome, postpartum thyroiditis, and amiodarone toxicity, respectively. Proptosis would indicate Graves disease, while a nodular thyroid gland would imply toxic multinodular goiter.


**12 Answer B.** Most patients with Graves disease are effectively treated with I-131 with only 10% requiring retreatment. Symptomatic improvement is usually noted by 3 weeks with full therapeutic effect typically in 3 to 6 months. Some patients may experience exacerbation of hyperthyroidism symptoms due to spillage of preformed thyroid hormone. Elderly patients with cardiac history and pediatric patients may benefit from pretreatment with methimazole to “cool down” the thyroid gland and beta blockade to prevent tachycardia.

One of the approaches to treating Graves disease is to use an empirical I-131 dose in the range of 8 to 15 mCi. Another approach takes into account the estimated size of the thyroid gland and 24-hour RAIU using the following formula: I-131 dose = (estimated thyroid gland size x 0.150 to 0.180 mCi/g of thyroid tissue)/24 hour RAIU.


13 **Answer C.** Compared to Graves disease, hyperthyroidism from toxic multinodular goiter (MNG) is generally more resistant to radioiodine therapy. This combined with lower RAIU by the thyroid (20% to 30%) in MNG requires about twice the amount of I-131 compared to Graves disease. The typical empirical I-131 dose ranges from 20 to 30 mCi. Similar approach is used in treating a toxic autonomously functioning thyroid nodule.


14 **Answer B.** Iodine deficiency-induced hypothyroidism would result in elevated radioiodine uptake due to increased stimulation from elevated TSH levels. This is rarely seen in developed countries in the present day and age. The remaining choices demonstrate decreased or absent radioiodine uptake in the thyroid gland.


15 **Answer D.** Iodine is concentrated in large amounts by the glandular tissue in the breast and is secreted in the breast milk. As such, all lactating women undergoing I-131 therapy should be asked to stop breast-feeding in order to minimize the radiation dose to the sensitive breast tissue and to prevent the infant’s exposure to I-131. Lactation and the ability of the breast tissue to concentrate large amounts of iodine stop 4 to 6 weeks after delivery or cessation of breast-feeding. As such, if possible, therapy should be delayed for approximately 6 weeks, and the patient should be initiated on dopamine agonist therapy to reduce the absorbed dose to the breast tissue. The patient should not resume breast-feeding for that child but may resume with the birth of another child.


16 **Answer B.** Radioiodine is concentrated and secreted by the glandular tissue of the breast. Unlike I-131, Tc-99m pertechnetate and I-123 have short half-lives and do not emit beta radiation. As such, breast-feeding may resume 48 hours after administration of I-123 and 24 hours after administration of Tc-99m pertechnetate.


17 **Answer B.** Serum thyroglobulin (Tg) is the most accurate tumor marker to detect recurrence of a well-differentiated thyroid carcinoma. It is not useful for poorly differentiated, anaplastic, or medullary forms of thyroid carcinoma. Please note that the presence of Tg antibody may compromise the accuracy of the Tg essay.


18 **Answer B.** Papillary thyroid carcinoma is the most common thyroid malignancy and represents about 80% to 90% of well-differentiated thyroid cancers. Well-differentiated thyroid cancers are usually iodine avid but not FDG avid. Whole-body scan with radioiodine is the most effective method for tumor detection, staging, and treatment planning in patients with differentiated thyroid carcinoma (DTC).