The Element on Your Ceiling: The Actinoids

An ionisation smoke detector holds about 1 microcurie of americium-241, a man-made actinoid. The actinoids are the fourteen elements thorium (90) to lawrencium (103), filling 5f: [Rn] $5f^{1\text{-}14}$ $6d^{0\text{-}1}$ $7s^2$. Because 5f, 6d and 7s are close in energy they show a wide range of oxidation states: +3 is common, but Th reaches +4, Pa +5, U +6 (as in uranyl UO_2^{2+}) and Np and Pu +7, after which the maximum falls. 5f electrons shield poorly, so the actinoid contraction is larger than the lanthanoid contraction. The metals are very reactive (boiling water gives oxide and hydride; HCl attacks them; nitric acid forms a protective oxide layer; alkalies have no action). All actinoids are radioactive: Th-232 (≈ 14 billion years) and U-238 (≈ 4.5 billion years) occur in nature, while the elements beyond uranium are man-made and the last ones survive only minutes to hours.

Name: Date: Score: ____ / 24

A. Fill in the blanks

1. The actinoids run from thorium (Z = 90) to ____ (Z = 103).

2. The general configuration of the actinoids is [Rn] $5f^{1\text{-}14}$ $6d^{0\text{-}1}$ ____.

3. The common oxidation state of all actinoids is ____.

4. The highest oxidation state shown by actinoids is ____.

5. The actinoid in household smoke detectors is ____-241.

B. True or False

6. Lanthanoids show a wider range of oxidation states than actinoids. True / False

7. The actinoid contraction is greater than the lanthanoid contraction. True / False

8. Only the later actinoids are radioactive. True / False

9. Thorium and uranium occur in nature in substantial amounts. True / False

10. Nitric acid dissolves actinoid metals rapidly. True / False

C. Assertion and reason

11. Assertion (A): Assertion: Actinoids show a greater range of oxidation states than lanthanoids. Reason: 5f, 6d and 7s orbitals have comparable energies.
Reason (R): Both true; the reason explains the assertion.

(a) Both A and R are true, and R explains A
(b) Both A and R are true, but R does not explain A
(c) A is true, R is false
(d) A is false, R is true

Answer: _____

12. Assertion (A): Assertion: Elements beyond uranium are made in reactors and accelerators. Reason: They are too short-lived to survive in nature in significant amounts.
Reason (R): Both true; the reason explains the assertion.

(a) Both A and R are true, and R explains A
(b) Both A and R are true, but R does not explain A
(c) A is true, R is false
(d) A is false, R is true

Answer: _____

D. Choose the correct option

13. Actinoids show many oxidation states because:

(a) 5f, 6d and 7s energies are close
(b) they are radioactive
(c) they have no f electrons
(d) they are heavy

Answer: _____

14. The oxidation state of U in UO_2^{2+} is:

(a) +6
(b) +2
(c) +4
(d) +3

Answer: _____

15. Which actinoids show +7?

(a) Np and Pu
(b) Th and Pa
(c) Cm and Bk
(d) Lr and No

Answer: _____

16. Boiling water converts actinoid metals into:

(a) oxide and hydride
(b) nitride
(c) carbide
(d) no change

Answer: _____

17. The half-life of thorium-232 is about:

(a) 14 billion years
(b) 14 years
(c) 14 days
(d) 14 minutes

Answer: _____

18. Alkalies on actinoid metals:

(a) have no action
(b) dissolve them
(c) form hydrides
(d) make them glow

Answer: _____

E. Numerical problems

19. Find the oxidation state of Pu in PuO_2^+ (charge +1).

20. How many actinoids are there from Th (90) to Lr (103)?

F. Short answer questions

21. Why do actinoids show a wide range of oxidation states?

22. What is the actinoid contraction and why is it larger than the lanthanoid contraction?

23. How does an ionisation smoke detector use americium-241?

G. Match the columns

24. Match each item in Column A with the correct item in Column B.

Column A	Column B	Your answer
1. Actinoids	(a) +3 common; Th +4, Pa +5, U +6, Np/Pu +7	1 → ____
2. Oxidation states	(b) Th (90) → Lr (103), [Rn] $5f^{1\text{-}14}$ $6d^{0\text{-}1}$ $7s^2$	2 → ____

Detailed solutions

1. lawrencium

2. $7s^2$

3. +3

4. +7

5. americium

6. False. Actinoids show the wider range (up to +7).

7. True. 5f electrons shield poorly.

8. False. All actinoids are radioactive.

9. True. Elements beyond uranium are man-made.

10. False. A protective oxide layer forms; HCl attacks them.

11. (a) Comparable energies allow more electrons to be used.

12. (a) Transuranium elements.

13. (a) 5f, 6d and 7s energies are close. Comparable energies.

14. (a) +6. $x - 4 = +2$.

15. (a) Np and Pu. Maximum oxidation state.

16. (a) oxide and hydride. NCERT 4.6.4.

17. (a) 14 billion years. Longer than the age of the universe.

18. (a) have no action. NCERT 4.6.4.

19. $x - 4 = +1$. **Answer: +5**

20. $103 - 90 + 1$. **Answer: 14**

21. Their 5f, 6d and 7s levels are close in energy, so different numbers of electrons can be removed or shared; early members reach +4 to +7.

22. The steady decrease in the size of atoms and M^{3+} ions from Th to Lr; it is larger element to element because 5f electrons shield the nuclear charge poorly.

23. Am-241 emits alpha particles that ionise the air between two plates, giving a small current; smoke particles reduce the current and the alarm sounds.

24. 1 → (b), 2 → (a).