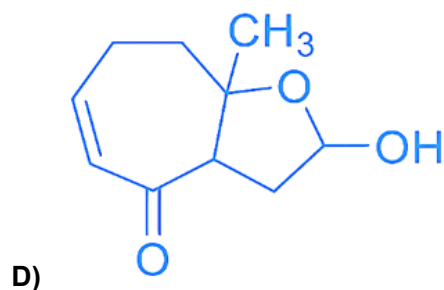
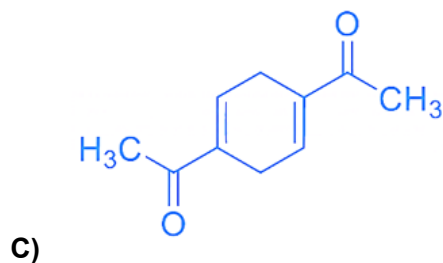
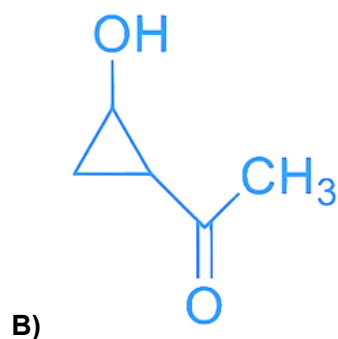
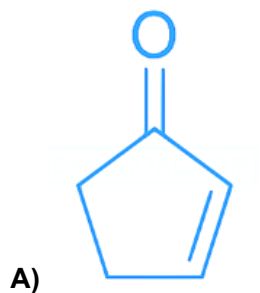
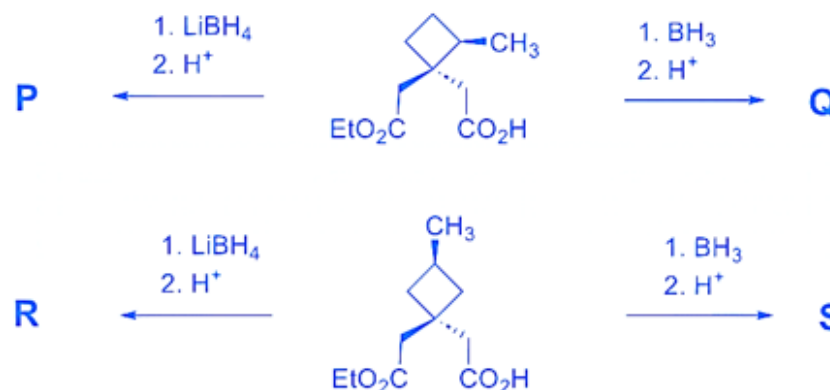


Chemistry

1. Natural rubber on complete ozonolysis ($O_3/Zn - H_2O$) gives compound X as the major product. X gives positive iodoform and Tollen's tests. X on heating with aqueous $NaOH$ gives Y as the major product. Y is

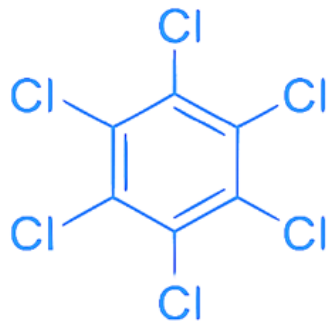
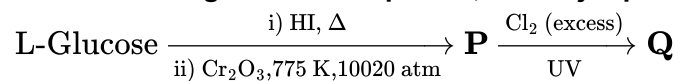


2. Considering $LiBH_4$ reduces an ester group to the corresponding alcohol and does not reduce a carboxylic acid group, the correct statement about the major products P , Q , R and S is:

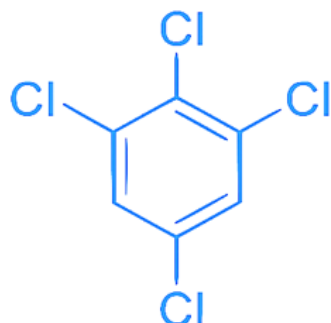


- A)** P & Q are identical, and R & S are diastereomers.
B) P & Q are diastereomers, and R & S are identical.
C) P & Q are diastereomers, and R & S are diastereomers.
D) P & Q are identical, and R & S are identical.

3. In the following reaction sequence, the major product Q is:



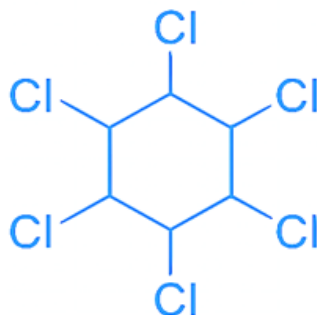
A)



B)



C)



D)

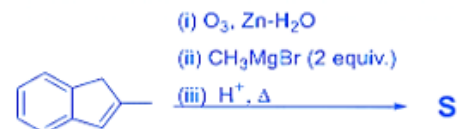
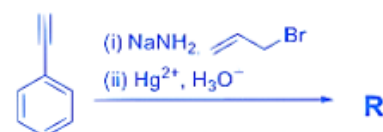
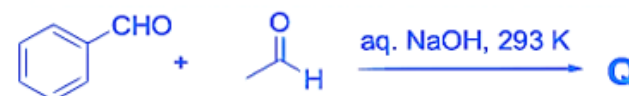
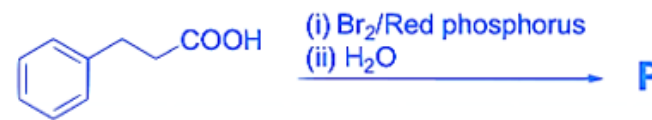
4. The major products obtained from the reactions in List-II are the reactants for the named reactions mentioned in List-I. Match List-II and choose the correct option.

List-I	List-II
(P) Etard reaction	(1) Acetophenone $\xrightarrow{\text{Zn-Hg, HCl}}$
(Q) Gattermann reaction	(2) Toluene $\xrightarrow[\text{(ii) SOCl}_2]{\text{(i) KMnO}_4, \text{KOH}, \Delta}$
(R) Gattermann-Koch reaction	(3) Benzene $\xrightarrow[\text{anhyd. AlCl}_3]{\text{CH}_3\text{Cl}}$
(S) Rosenmund reduction	(4) Aniline $\xrightarrow[272-278 \text{ K}]{\text{NaNO}_2/\text{HCl}}$
	(5) Phenol $\xrightarrow{\text{Zn}, \Delta}$

A) P $\rightarrow$ 2; Q $\rightarrow$ 4; R $\rightarrow$ 1; S $\rightarrow$ 3 B) P $\rightarrow$ 1; Q $\rightarrow$ 3; R $\rightarrow$ 5; S $\rightarrow$ 2

C) P $\rightarrow$ 3; Q $\rightarrow$ 2; R $\rightarrow$ 1; S $\rightarrow$ 4 D) P $\rightarrow$ 3; Q $\rightarrow$ 4; R $\rightarrow$ 5; S $\rightarrow$ 2

5. Monocyclic compounds P, Q, R and S are the major products formed in the reaction sequences given below.



having the highest number of unsaturated carbon atom(s) is:

A) P

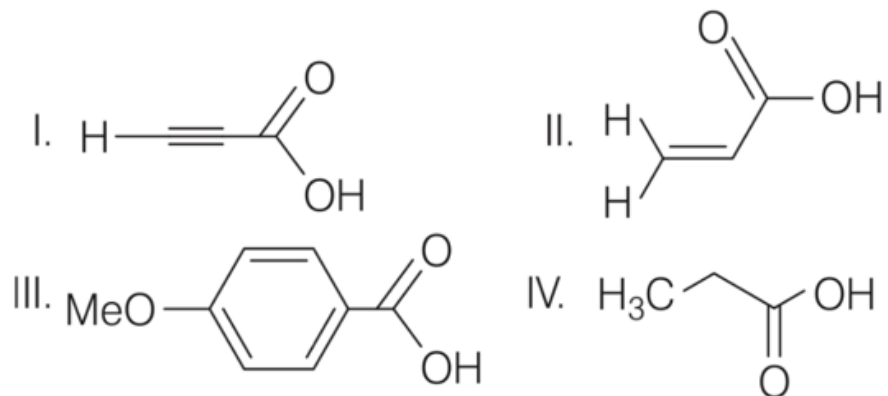
B) Q

C) R

D) S

The product

6. The correct order of acid strength of the following carboxylic acids is:



A) III > II > I > IV

B) I > II > III > IV

C) II > I > IV > III

D) I > III > II > IV

7. The reactions, $Q \rightarrow R$ and $R \rightarrow S$, are

A) Dehydration and Friedel-Crafts acylation

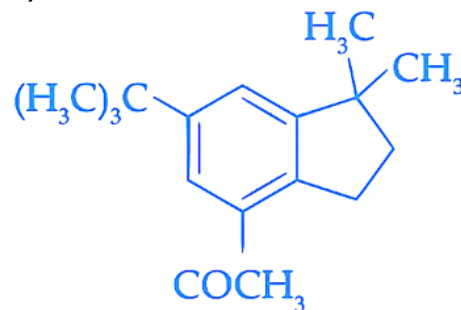
B) Aromatic sulfonation and Friedel-Crafts acylation

C) Friedel-Crafts alkylation, dehydration and Friedel-Crafts acylation

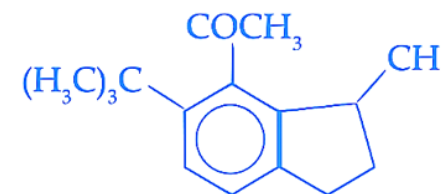
D) Friedel-Crafts alkylation and Friedel-Crafts acylation

8. The product S is

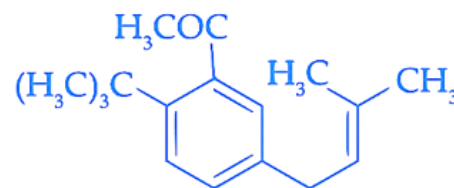
A)



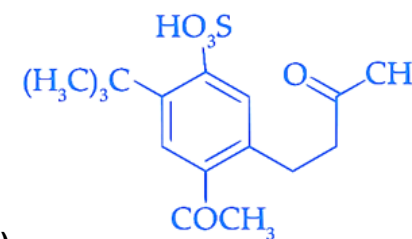
B)



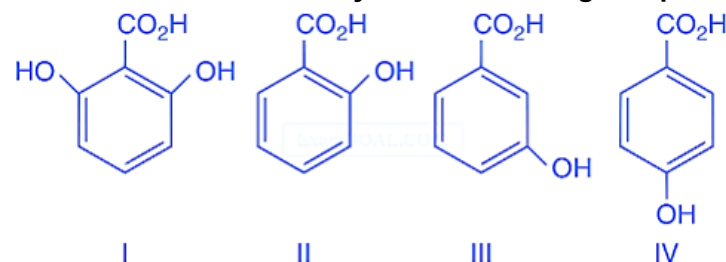
C)



D)



9. The correct order of acidity for the following compounds is:



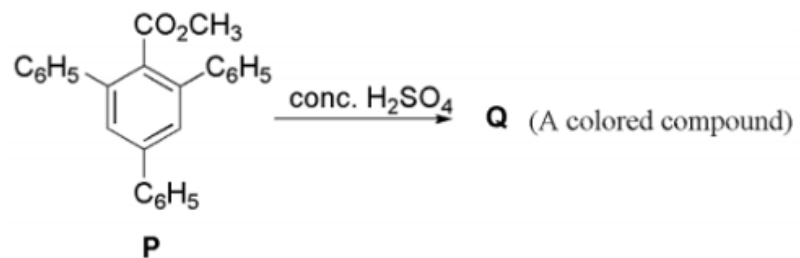
A) I > II > III > IV

B) III > I > II > IV

C) III > IV > II > I

D) I > III > IV > II

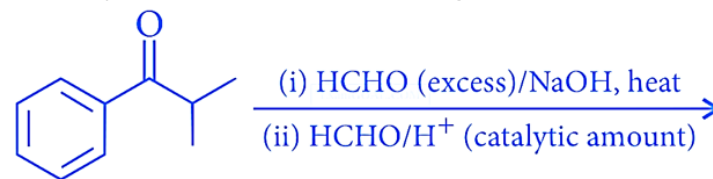
10. In the following reaction, compound Q is obtained from compound P via an ionic intermediate:



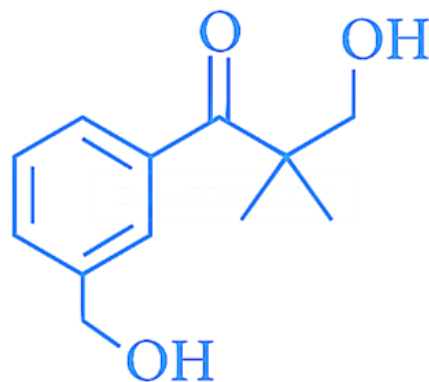
What is the degree of unsaturation of Q?

- A) 14 B) 16
C) 18 D) 20

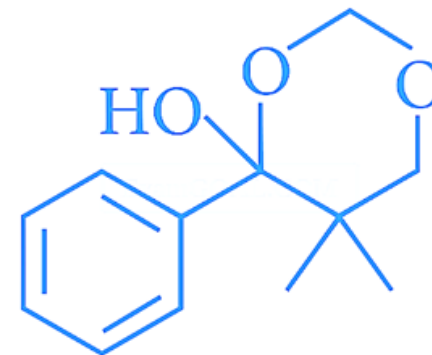
11. The major product of the following reaction sequence is:



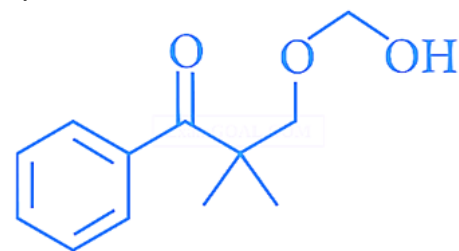
A)



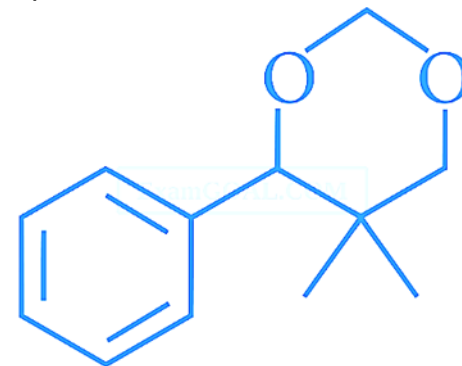
B)



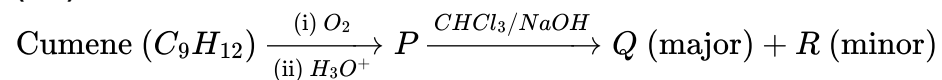
C)



D)



12. The correct statements about the following reaction sequence is (are)



$Q \xrightarrow[\text{PhCH}_2\text{Br}]{\text{NaOH}} S$ A. *R* is steam volatile. B. *Q* gives dark violet coloration with 1% aqueous $FeCl_3$ solution. C. *S* gives yellow precipitate with 2,4-dinitrophenylhydrazine. D. *S* gives dark violet coloration with 1% aqueous $FeCl_3$ solution.

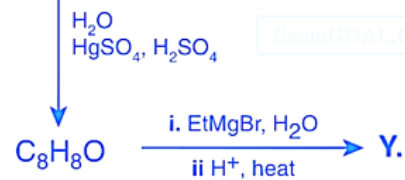
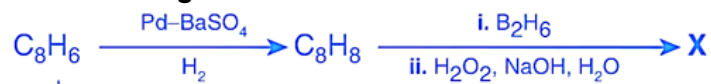
A) B, C

B) A, B

C) D, A

D) A, C

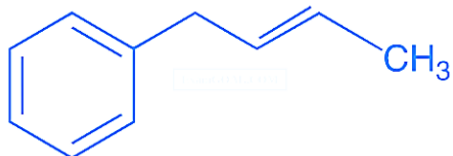
13. In the following reactions:



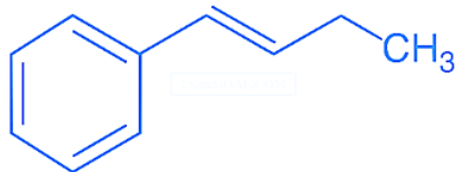
compound Y is:

The major

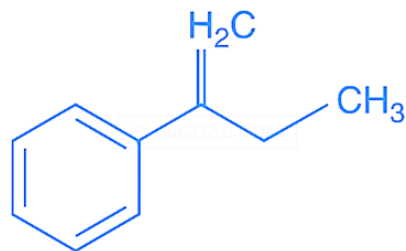
A)



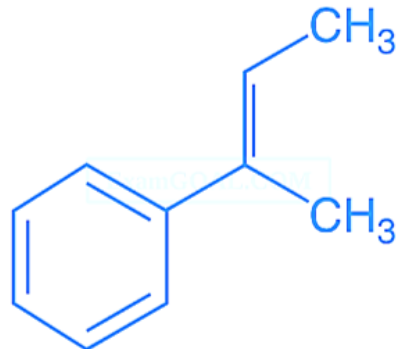
B)



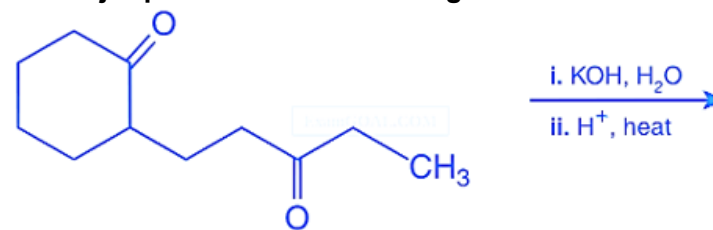
C)



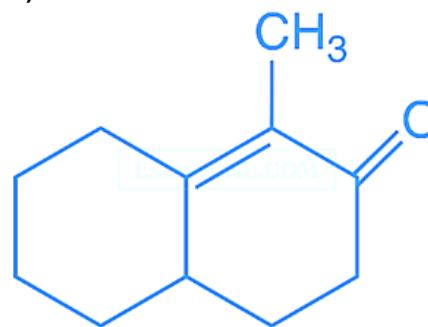
D)



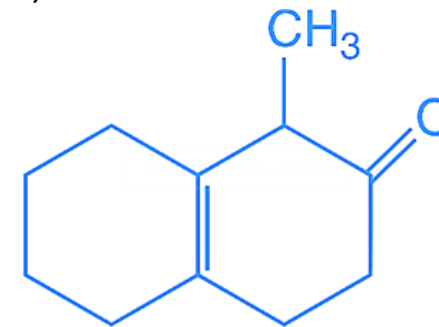
14. The major product of the following reaction is:



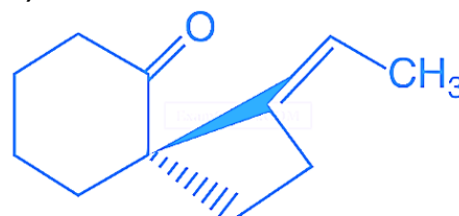
A)



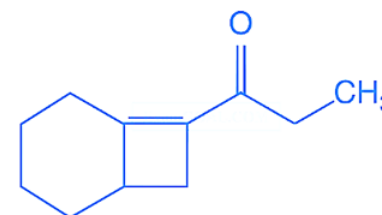
B)



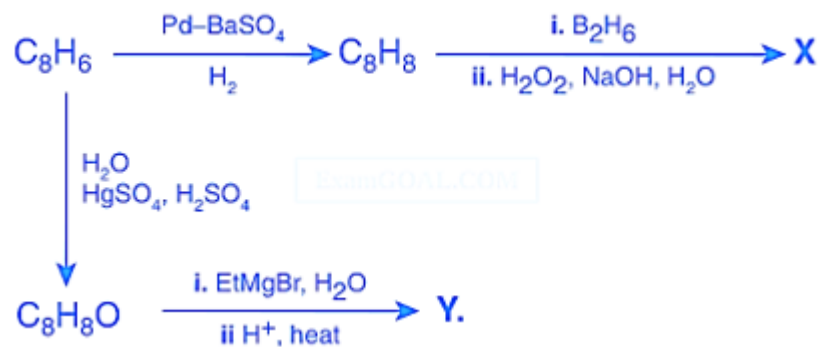
C)



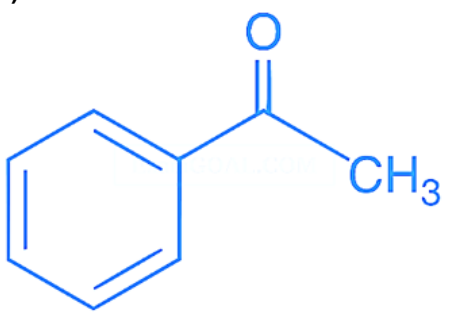
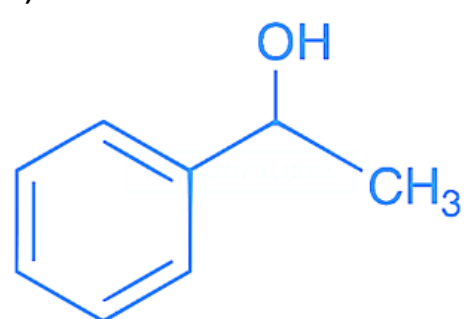
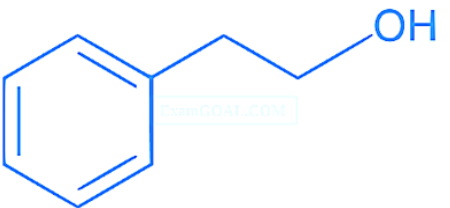
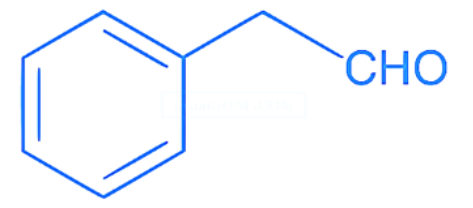
D)



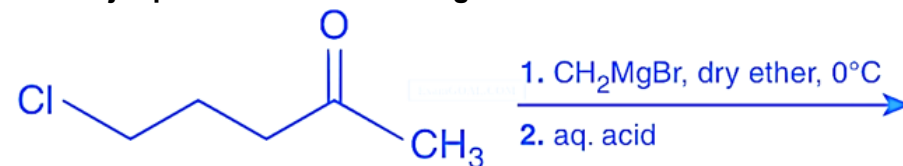
15. In the following reaction scheme, starting with a hydrocarbon of molecular formula C_8H_6 :

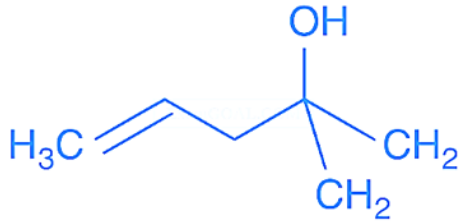
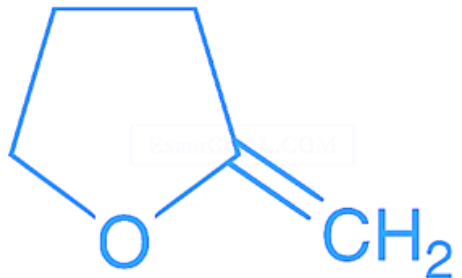
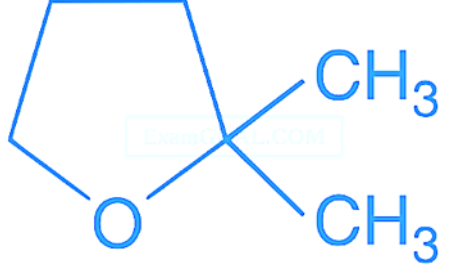


Compound X is:

- A) 
- B) 
- C) 
- D) 

16. The major product in the following reaction is:

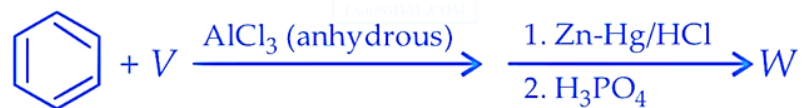
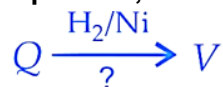


- A) 
- B) 
- C) 
- D) 

17. Consider all possible isomeric ketones including stereoisomers of $MW = 100$. All these isomers are independently reacted with $NaBH_4$ (Note: stereoisomers are also reacted separately). The total number of ketones that give a racemic product(s) is/are

- A) 3
B) 4
C) 5
D) 6

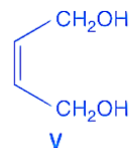
18. In the following reaction sequences, V and W are, respectively,



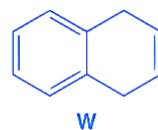
A)



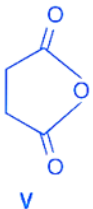
B)



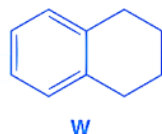
and



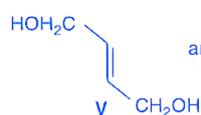
C)



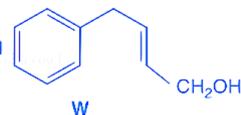
and



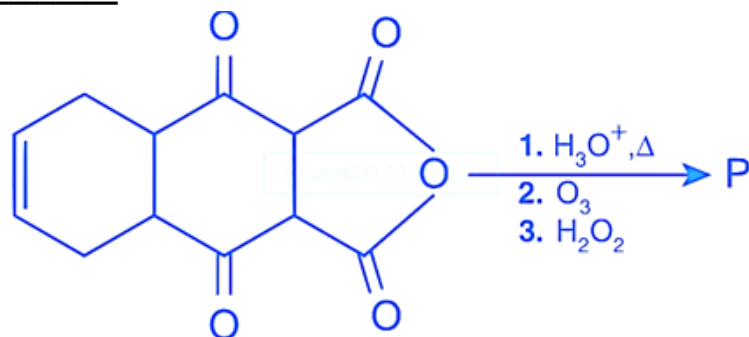
D)



and



19. The total number of carboxylic acid groups in the product P is _____.



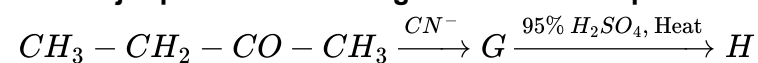
A) 1

B) 2

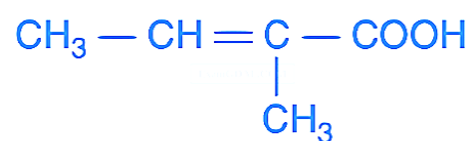
C) 3

D) 4

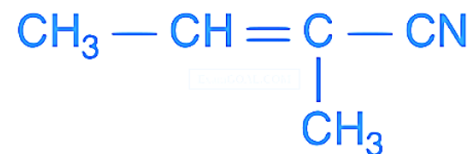
20. The major product *H* of the given reaction sequence is



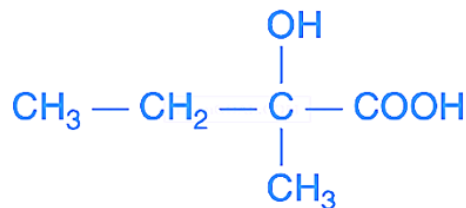
A)



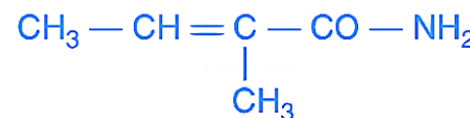
B)



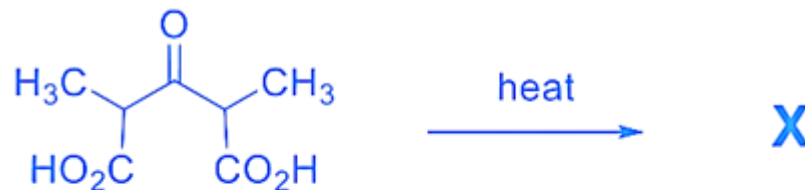
C)



D)



21. The sum of total number of carbonyl groups ($>C=O$) present in the major products *X* and *Y* in the following reactions is _____.

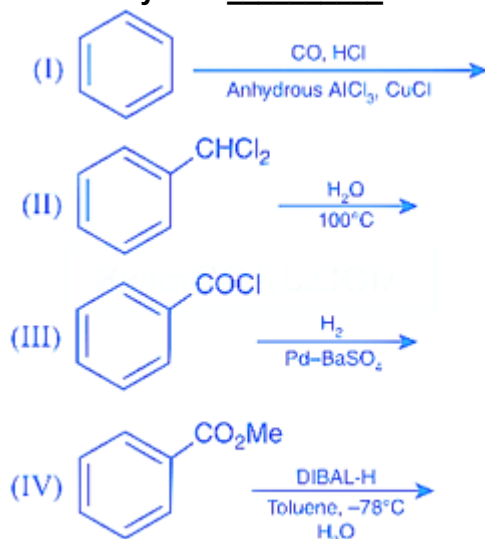


22. Sum of number of oxygen atoms in *S* and *T* is _____.

23. The molecular weight of *U* is _____.

24. Complete reaction of acetaldehyde with excess formaldehyde, upon heating with conc. NaOH solution, gives *P* and *Q*. Compound *P* does not give Tollens' test, whereas *Q* on acidification gives positive Tollens' test. Treatment of *P* with excess cyclohexanone in the presence of catalytic amount of *p*-toluenesulfonic acid (PTSA) gives product *R*. Sum of the number of methylene groups ($-\text{CH}_2-$) and oxygen atoms in *R* is _____.

25. Among the following, the number of reactions that produces benzaldehyde is _____.



Maths

26. Let $f(x) = \int \frac{2x}{(x^2+2)(x^2+3)} dx$. If $f(1) = \log_e 3 - \log_e 4$, then $f(2)$ is equal to:

- A) $\log_e 6 - \log_e 7$ B) $\log_e 5 - \log_e 6$
C) $\log_e 7 - \log_e 8$ D) $\log_e 4 - \log_e 5$

27. Let $I(x) = \int \frac{x^2(x \csc^2 x - \cot x)}{(x \cot x - 1)^2} dx$. If $I(0) = 0$, then $I(\frac{\pi}{4})$ is equal to:

- A) $\log_e \frac{(\pi-4)^2}{16} - \frac{\pi^2}{4(\pi-4)}$ B) $\log_e \frac{(\pi-4)^2}{32} - \frac{\pi^2}{4(\pi-4)}$
C) $\log_e \frac{(\pi-4)^2}{16} + \frac{\pi^2}{4(\pi-4)}$ D) $\log_e \frac{(\pi-4)^2}{32} + \frac{\pi^2}{4(\pi-4)}$

28. For $I(x) = \int \frac{\sec^2 x - 2024}{\sin^{2024} x} dx$, if $I(\frac{\pi}{4}) = 2^{1012}$, then:

- A) $3^{1011} I(\frac{\pi}{3}) - I(\frac{\pi}{6}) = 0$ B) $3^{1011} I(\frac{\pi}{6}) - I(\frac{\pi}{3}) = 0$
C) $3^{1012} I(\frac{\pi}{3}) - I(\frac{\pi}{6}) = 0$ D) $3^{1012} I(\frac{\pi}{6}) - I(\frac{\pi}{3}) = 0$

29. The integral $\int \left(\frac{x}{x \cos x - \sin x} \right)^2 dx$ is equal to (where C is a constant of integration):

- A) $\cot x + \frac{x \csc x}{x \cos x - \sin x} + C$ B) $\frac{x \csc x}{x \cos x - \sin x} - \cot x + C$
C) $\tan x + \frac{x \sec x}{x \cos x - \sin x} + C$ D) $\cot x - \frac{x \csc x}{x \cos x - \sin x} + C$

30. The integral $\int \sin(\log_e x) dx$ is equal to: (where C is a constant of integration)

- A) $\frac{x}{2} [\sin(\log_e x) + \cos(\log_e x)] + C$ B) $\frac{x}{2} [\cos(\log_e x) - \sin(\log_e x)] + C$
C) $x [\sin(\log_e x) - \cos(\log_e x)] + C$ D) $\frac{x}{2} [\sin(\log_e x) - \cos(\log_e x)] + C$

31. The value of the integral $\int_{\pi/12}^{\pi/6} \frac{dx}{1 + \sqrt{\tan 2x}}$ is:

- A) $\frac{\pi}{6}$ B) $\frac{\pi}{12}$
C) $\frac{\pi}{24}$ D) $\frac{\pi}{48}$

32. The value of $\int_{-\pi/2}^{\pi/2} \frac{\sin^2 x}{1 + e^{\sin x}} dx$ is:

- A) π B) $\frac{\pi}{2}$
C) $\frac{\pi}{4}$ D) $\frac{\pi}{8}$

33. The value of $\int_{-\pi}^{\pi} \frac{\sin^2 x}{1 + 5^x} dx$ is:

- A) 2π B) π
C) $\frac{\pi}{2}$ D) $\frac{\pi}{4}$

34. The value $\int_0^1 \sqrt[3]{4x^3 - 6x^2 + 4x - 1} dx$ is equal to:

- A) 1 B) 2
C) 0 D) -1

35. $\int_{-\pi}^{\pi} \frac{x(1 + \sin x)}{1 + \cos^2 x} dx =$

- A) $\frac{\pi^2}{2}$ B) π^2
C) 0 D) $\frac{\pi}{2}$

36. $\int \frac{\sin x - x \cos x}{x(x + \sin x)} dx =$

- A) $\log \left| \frac{x}{x + \sin x} \right| + c$ B) $-\log \left| \frac{x}{x + \sin x} \right| + c$
C) $\log \left| \frac{x + \sin x}{2x} \right| + c$ D) $-\log \left| \frac{x + \sin x}{2x} \right| + c$

37. Integral of $\sqrt{1 + 2 \tan x (\tan x + \sec x)}$ with respect to x is:

- A) $2 \ln \left| \cos \frac{x}{2} - \sin \frac{x}{2} \right| + c$ B) $-2 \ln \left| \cos \frac{x}{2} - \sin \frac{x}{2} \right| + c$
C) $2 \ln \left| \sin \frac{x}{2} \right| + c$ D) $\ln |\sec x| \cdot \ln |\sec x + \tan x| + c$

38. $\int \frac{e^{\tan x}}{\cos^2 x} (2 \ln \sec x + \sin 2x) dx =$

- A) $2e^{\tan x} \ln(\sec x) + c$ B) $-2e^{\tan x} \ln(\sec x) + c$
C) $e^{\tan x} \ln(\sec x) + c$ D) $e^{\tan x} \ln(\cos x) + c$

39. $\int \frac{1}{1 - \cos x + \sin x} dx = \log_e |f(x)| + c$, then $f(x) =$

- A) $\frac{1 + \tan \frac{x}{2}}{\tan \frac{x}{2}}$ B) $\frac{\tan \frac{x}{2}}{1 + \tan \frac{x}{2}}$
C) $1 + \tan \frac{x}{2}$ D) $1 - \tan \frac{x}{2}$

40. $\int_0^1 \frac{dx}{(3 + x - x^2)(1 + e^{1-2x})} =$

- A) $\frac{1}{2\sqrt{13}} \log_e \left(\frac{\sqrt{13} + 1}{\sqrt{13} - 1} \right)$ B) $\frac{1}{\sqrt{13}} \log_e \left(\frac{\sqrt{13} + 1}{\sqrt{13} - 1} \right)$
C) $\frac{1}{\sqrt{13}} \log_e \left(\frac{\sqrt{13} - 1}{\sqrt{13} + 1} \right)$ D) $\frac{1}{2\sqrt{13}} \log_e \left(\frac{\sqrt{13} + 1}{\sqrt{13}} \right)$

41. $\int_1^5 (x - 1)(x - 2)(x - 4)(x - 5) dx =$

- A) 0 B) $\frac{32}{15}$
C) $\frac{16}{15}$ D) $-\frac{32}{15}$

42. $\int_0^{1/\sqrt{2}} \frac{\cos^{-1} x}{(1 - x^2)^{3/2}} dx =$

- A) $\frac{\pi}{4} - \frac{1}{2} \log 2$ B) $\frac{\pi}{4} + \frac{1}{2} \log 2$
C) $\frac{\pi}{2} + \log 2$ D) $\frac{\pi}{2} - \log 2$

43. The value of

$$\int_{-\pi/2}^{\pi/2} \left(\sqrt{1 + \sin x + \sin^2 x} - \sqrt{1 - \sin x + \sin^2 x} \right) dx \text{ is:}$$

- A) 0
B) 1
C) -1
D) π

44. $\int_0^{\pi/2} \frac{\sin^{3/2} x}{\sin^{3/2} x + \cos^{3/2} x} dx =$

- A) π
B) $\frac{\pi}{2}$
C) $\frac{\pi}{4}$
D) $\frac{\pi}{3}$

45. $\int_0^{\pi/4} \frac{d\theta}{1 + \tan \theta} =$

- A) $\frac{\pi}{8} + \frac{1}{4} \log 2$
B) $\frac{\pi}{8} - \frac{1}{4} \log 2$
C) $\frac{\pi}{4} + \frac{1}{2} \log 2$
D) $\frac{\pi}{4}$

46. Let $\int \frac{3 - \tan x}{2 + \tan x} dx = \alpha x + \log_e |\beta \sin x + \gamma \cos x| + C$, where C is the constant of integration. Then $\alpha + \frac{\gamma}{\beta}$ is equal to:

47. The value of $\int_0^{10\pi} (\sin^6 x + \cos^6 x) dx$ is equal to $k\pi$, where k is $\frac{25}{x}$. Find X value

48. If $\int_{-\pi/2}^{\pi/2} \frac{48x^2 \sin^2 x}{1 + e^x} dx = \pi(\alpha\pi^2 + \beta)$, where $\alpha, \beta \in \mathbb{Z}$, then $(\alpha + \beta)^2$ equals:

49. The integral $\int_{\pi/2}^{\pi} \frac{dx}{1 - \cos x}$ is equal to:

50. $\int_0^{\pi/2} \frac{\sin^5 x}{\sin^5 x + \cos^5 x} dx = \frac{\pi}{x}$, what is the value of x ?

Physics

51. The binding energy for the following nuclear reactions are

expressed in MeV. ${}^6_3\text{Li} + {}^1_0\text{n} \rightarrow {}^7_3\text{Li} + 16\text{MeV}$

${}^7_3\text{Li} + {}^1_0\text{n} \rightarrow {}^8_3\text{Li} - 2\text{MeV}$ If X_6, X_7, X_8 denote the stability of ${}^6_3\text{Li}, {}^7_3\text{Li}$ and ${}^8_3\text{Li}$, respectively, then the correct order is:

- A) $X_7 < X_8 < X_6$
B) $X_7 > X_8 > X_6$
C) $X_7 > X_8 < X_6$
D) $X_7 = X_8 = X_6$

52. Which of the following pair of nuclei are isobars of the element?

- A) ${}^2_1\text{H}$ and ${}^3_1\text{H}$
B) ${}^{206}_{82}\text{Pb}$ and ${}^{207}_{83}\text{Bi}$
C) ${}^{40}_{19}\text{K}$ and ${}^{40}_{20}\text{Ca}$
D) ${}^{12}_6\text{C}$ and ${}^{13}_6\text{C}$

53. Two radioactive substances A and B of mass numbers 208 and 204 respectively, shows spontaneous α -decay with same Q value of 2 MeV. The ratio of energies of α -rays produced by A and B is ____.

- A) $\frac{2600}{2601}$
B) $\frac{2601}{2600}$
C) $\frac{2597}{2600}$
D) $\frac{2601}{2597}$

54. The energy released when a deuterium nucleus ${}^2_1\text{H}$ combines with a tritium nucleus ${}^3_1\text{H}$ to form a helium nucleus ${}^4_2\text{He}$ and a neutron is ____ MeV. Take binding energies per nucleon of ${}^2_1\text{H}, {}^3_1\text{H}$, and ${}^4_2\text{He}$ as 1.1 MeV, 2.8 MeV, and 7.2 MeV, respectively.

- A) 18.2 MeV
B) 16.8 MeV
C) 20.4 MeV
D) 12.6 MeV

55. Assuming the experimental mass of ${}^{13}_6\text{C}$ atom is $13.00335u$, the mass defect of the ${}^{13}_6\text{C}$ atom is ____ u . Given: Mass of proton = $1.00727u$, mass of neutron = $1.00866u$.

- A) $0.09089u$
B) $0.10089u$
C) $0.11089u$
D) $0.12089u$

Take $m(^{60}_{27}\text{Co}) = 59.9340\text{ u}$, mass of hydrogen atom $m_H = 1.007825\text{ u}$, mass of neutron $m_n = 1.008665\text{ u}$, and $1\text{ u} = 931\text{ MeV}/c^2$.

- A) 7.84 MeV** **B) 8.74 MeV**
C) 8.04 MeV **D) 9.12 MeV**

57. Assertion (A): The density of the iron ${}^{56}_{26}\text{Fe}$ nucleus is greater than that of the carbon ${}^{12}_6\text{C}$ nucleus. **Reason (R):** The radius of a nucleus having mass number A is proportional to $A^{1/3}$.

- A)** (A) is correct but (R) is not correct **B)** Both (A) and (R) are correct but (R) is not the correct explanation of (A)
- C)** (A) is not correct but (R) is correct **D)** Both (A) and (R) are correct and (R) is the correct explanation of (A)

58. Match List-I with List-II.

List-I	List-II
A. ${}^1_0n + {}^{235}_{92}\text{U} \rightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 3 {}^1_0n$	I. Chemical reaction
B. ${}^2_1\text{H} + {}^2_1\text{H} \rightarrow {}^3_2\text{He} + {}^1_0n$	II. Fusion with +ve Q value
C. $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$	III. Fission
D. ${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0n$	IV. Fusion with -ve Q value

- A)** A-III, B-IV, C-I, D-II
B) A-III, B-II, C-I, D-II
C) A-II, B-III, C-I, D-IV
D) A-I, B-II, C-III, D-IV

59. Choose the correct nuclear process for electron capture from the options below, where p is proton, n is neutron, e^- is electron, e^+ is positron, ν is neutrino, and $\bar{\nu}$ is antineutrino.

- A)** $p \rightarrow n + e^+ + \nu$ **B)** $p + e^- \rightarrow n + \nu$
C) $p \rightarrow n + e^- + \bar{\nu}$ **D)** $n + e^- \rightarrow p + \bar{\nu}$

60. A radioactive nucleus n_2 has twice the decay constant as compared to the decay constant of another radioactive nucleus n_1 . If the initial number of both nuclei is the same, what is the ratio of the number of nuclei of n_2 to the number of nuclei of n_1 after two half-lives of n_1 ?

- A)** $\frac{1}{4}$
- B)** $\frac{1}{8}$
- C)** 4
- D)** 8

61. If M_0 is the mass of isotope $^{16}_8\text{O}$, M_p and M_n are the masses of proton and neutron, respectively, then the nuclear binding energy of the isotope is:

- A)** $(8M_p + 8M_n - M_0)c^2$ **B)** $(M_0 - 8M_p - 8M_n)c^2$
C) $(M_0 - 16M_n)c^2$ **D)** $(8M_p - M_0)c^2$

62. In a hypothetical fission reaction ${}_{94}^{239}\text{Pu} \rightarrow {}_{54}^{140}\text{Xe} + {}_{38}^{96}\text{Sr} + 3R$ the identity of the emitted particles R is:

- A) Proton**
- B) Neutron**
- C) Electron**
- D) γ -rays**

63. The disintegration energy Q for the nuclear fission of ${}_{92}^{235}\text{U}$ into ${}_{56}^{141}\text{Ba}$, ${}_{36}^{92}\text{Kr}$ and two neutrons is ____ MeV. Given atomic masses of ${}_{92}^{235}\text{U} = 235.0439\text{ u}$, ${}_{56}^{141}\text{Ba} = 140.9144\text{ u}$, ${}_{36}^{92}\text{Kr} = 91.9262\text{ u}$, mass of neutron = 1.00866 u , and $c^2 = 931\text{ MeV/u}$.

- A) 163.2 MeV** **B) 173.1 MeV**
C) 183.6 MeV **D) 193.4 MeV**

64. The half-life of a radioactive nucleus is 4 years. The fraction of the original sample that would decay in 12 years is:

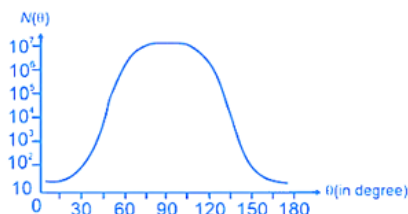
- A)** $\frac{1}{8}$
- B)** $\frac{3}{4}$
- C)** $\frac{7}{8}$
- D)** $\frac{1}{4}$

65. In the nuclear reaction ${}_{90}^{232}\text{Th} \rightarrow {}_{88}^{228}\text{Ra} + {}_2^4\text{He} + Q$ the approximate amount of energy released will be: Given: $m({}_{90}^{232}\text{Th}) = 232.03805\text{ u}$
 $m({}_{88}^{228}\text{Ra}) = 228.03107\text{ u}$ $m({}_2^4\text{He}) = 4.00260\text{ u}$
 $1\text{ u} = 931.5\text{ MeV}/c^2$

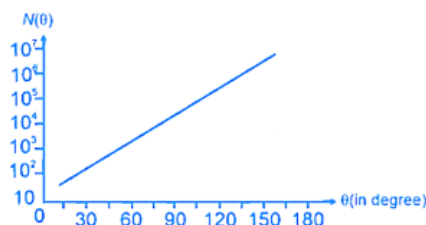
- A) 2.04 MeV
 B) 4.08 MeV
 C) 6.12 MeV
 D) 8.16 MeV

66. In Geiger-Marsden experiment, the number of scattered α -particles $N(\theta)$ is plotted as a function of scattering angle θ . Which of the following options represents the correct plot?

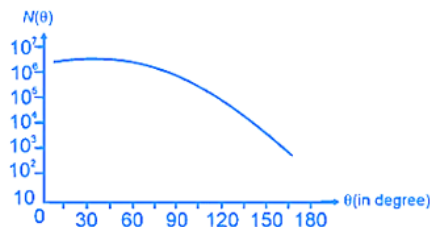
A)



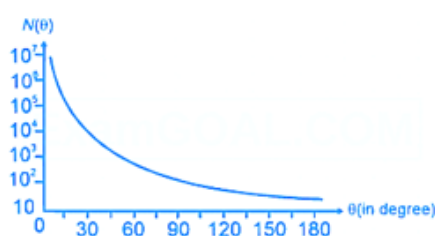
B)



C)



D)



67. Select the correct statements among the following: A. Cadmium rods are used to control the rate of fission in a nuclear reactor. B. In β^- decay, the mass number of the nucleus remains unchanged while the atomic number increases by one. C. The penetrating power of α particles is less than that of β particles of the same energy. D. The moderator in a nuclear reactor is used to speed up fast neutrons to higher velocities. Choose the most appropriate answer from the options given below:

- A) A, B and D only
 B) B, C and D only
 C) A, B and C only
 D) A, C and D only

68. ${}_{92}^{236}\text{X} \xrightarrow{\alpha} \text{Y} \xrightarrow{e^+} \text{Z} \xrightarrow{\beta^-} \text{P} \xrightarrow{e^-} \text{Q}$ In the nuclear emission stated above, the mass number and atomic number of the product Q respectively, are

- A) 236, 90
 B) 232, 91
 C) 232, 89
 D) 228, 91

69. In the given nuclear reaction, the element X is ${}_{90}^{234}\text{Th} \rightarrow \text{X} + e^- + \bar{\nu}$

- A) ${}_{91}^{234}\text{Pa}$
 B) ${}_{88}^{230}\text{Ra}$
 C) ${}_{89}^{234}\text{Ac}$
 D) ${}_{92}^{238}\text{U}$

70. A nucleus of mass number 280 splits into two nuclei having mass number 216 and 64. The ratio of radius of two daughter nuclei respectively is

- A) 2 : 3
 B) 9 : 4
 C) 27 : 8
 D) 3 : 2

71. The half life of a radioactive substance is 15 minutes. In how much time, the activity of substance drops to 1/32 th of its initial value___minutes?

72. The half life of a radioactive substance is 30 minutes. In how much time, the activity of substance drops to $\left(\frac{1}{64}\right)^{th}$ of its initial value?

73. For a radioactive material, half-life is 25 minutes. If initially there are 1200 number of nuclei, the time taken (in minutes) for the disintegration of 1050 nuclei is

74. The half-life of a radioactive substance is 25 minutes. The time (in minutes) taken between 20% decay and 90% decay of the same radioactive substance is

75. Consider the following nuclear reaction: $^{226}\text{Ra} \rightarrow ^{222}\text{Rn} + ^4\text{He}$
Take masses of ^{226}Ra , ^{222}Rn and ^4He as 226.025 u , 222.016 u and 4.003 u , respectively. The Q value for the reaction, in keV, is:
[Given: $1\text{ u} = 931.5\text{ MeVc}^{-2}$]

ANSWER KEY

Chemistry

1.	1	8.	1	15.	2	22.	2
2.	3	9.	1	16.	4	23.	93018
3.	4	10.	3	17.	3	24.	18
4.	4	11.	4	18.	1	25.	4
5.	4	12.	1	19.	2		
6.	2	13.	4	20.	1		
7.	4	14.	1	21.	4		

Maths

26.	1	33.	3	40.	2	47.	4
27.	2	34.	3	41.	2	48.	49
28.	1	35.	1	42.	2	49.	1
29.	2	36.	1	43.	1	50.	4
30.	4	37.	2	44.	3		
31.	3	38.	1	45.	1		
32.	3	39.	2	46.	3		

Physics

51.	2	58.	2	65.	2	72.	180
52.	3	59.	2	66.	4	73.	75
53.	2	60.	1	67.	3	74.	75
54.	1	61.	1	68.	2	75.	5589
55.	2	62.	2	69.	1		
56.	2	63.	2	70.	4		
57.	3	64.	3	71.	75		

SOLUTIONS

Q1.

Answer: A

Explanation:

Natural rubber is a polymer of isoprene (cis-1,4-polyisoprene). Complete ozonolysis of natural rubber cleaves its double bonds to yield levulinic aldehyde (4-oxopentanal) as the major product, which serves as compound *X*. Since *X* contains both a methyl ketone group (giving a positive iodoform test) and an aldehyde group (giving a positive Tollen's test), upon heating with aqueous NaOH, it undergoes an intramolecular aldol condensation via the more stable enolate, followed by dehydration to yield the major cyclic α, β -unsaturated carbonyl product *Y*.

Q2.

Answer: C

Explanation:

LiBH_4 selectively reduces the ester group (EtO_2C) to a primary alcohol while leaving the carboxylic acid group (CO_2H) unaffected. Similarly, BH_3 selectively reduces the carboxylic acid group to an alcohol while leaving the ester group unchanged. Depending on which group is reduced in the cis- and trans-isomers of the starting compounds, the resulting products P, Q, R, and *S* retain geometric isomerism (cis/trans configurations around the ring system), making the respective pairs stereoisomers that are not mirror images of each other, i.e., diastereomers.

Q3.

Answer: D

Explanation:

Treatment of L-Glucose with HI and Δ reduces all the hydroxyl groups completely to give *n*-hexane (**P**). Subsequent exhaustive chlorination of *n*-hexane under Cl_2/UV conditions yields hexachlorocyclohexane isomers (or a specific stereoisomer of benzene hexachloride, depending on intermediate aromatization/chlorination steps typical for such JEE Advanced sequence questions involving sugar-to-aromatic conversions). Based on the reaction path: 1. Reduction of L-Glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) with HI, Δ produces hexane. 2. Cyclization and aromatization under high temperature/pressure with Cr_2O_3 forms benzene. 3. Addition of excess Cl_2 in the presence of UV light gives hexachlorocyclohexane (Gammaxane isomer).

Q4.

Answer: D

Explanation:

Each named reaction in requires a specific starting organic reactant. By determining the major organic product formed in each sequence of , we can correctly match the reactant needed for each named reaction.

Q5.

Answer: D

Explanation:

To determine which product has the highest number of unsaturated carbon atoms, we analyze each reaction sequence to find the degree of unsaturation and double/triple bonds present in the major monocyclic products *P*, *Q*, *R*, and *S*. Compound *S* undergoes extensive dehydration following Grignard addition to a dicarbonyl system, forming an extended conjugated system with the highest number of unsaturated (sp and sp^2) carbon atoms among the choices.

Q6.

Answer: B

Explanation:

The acid strength of carboxylic acids depends on the stability of the corresponding carboxylate anion, which is governed by inductive, resonance, and field effects. Electron-withdrawing groups stabilize the anion and increase acidity, while electron-donating groups destabilize it and decrease acidity.

Q7.

Answer: D

Explanation:

The reaction sequence involves the introduction of alkyl and acyl groups into the aromatic ring. Specifically, $Q \rightarrow R$ represents Friedel-Crafts alkylation where an alkyl group is introduced using an alkylating agent in the presence of a Lewis acid catalyst such as anhydrous $AlCl_3$. Following this, $R \rightarrow S$ represents Friedel-Crafts acylation where an acyl group is introduced using an acyl halide or anhydride in the presence of a Lewis acid catalyst.

Q8.

Answer: A

Explanation:

The reaction sequence typically involves Friedel-Crafts acylation, reduction, and subsequent ring closure or alkylation steps to form a polycyclic aromatic ketone. Analyzing the positions of the tert-butyl group, the acetyl ($COCH_3$) group, and the gem-dimethyl substituents on the fused ring system confirms that option A represents the correct major product S.

Q9.

Answer: A

Explanation:

The acidity of substituted benzoic acids depends significantly on ortho-effects, resonance, and intramolecular hydrogen bonding. Compound I (2,6-dihydroxybenzoic acid) has two ortho-hydroxyl groups, which cause strong intramolecular hydrogen bonding and significant steric inhibition of resonance, forcing the carboxylate anion out of the plane of the benzene ring. This stabilizes the conjugate base immensely through charge dispersal and makes it the most acidic. Compound II (salicylic acid) has one ortho-hydroxyl group, providing similar stabilization to a lesser extent. Compounds III (meta) and IV (para) lack the ortho-effect, with para-hydroxy exhibiting resonance-donating electron density that decreases acidity compared to meta-hydroxy.

Q10.

Answer: C

Explanation:

Compound (P) undergoes an intramolecular electrophilic aromatic substitution in the presence of concentrated H_2SO_4 via an ionic intermediate to form a cyclic, colored compound (Q). The degree of unsaturation (double bond equivalent, DBE) of Q is calculated by counting its total rings and π bonds.

Q11.

Answer: D

Explanation:

The reaction sequence involves two key steps: 1. Aldol Reaction followed by Cannizzaro Reaction: The starting material is a ketone containing α -hydrogens adjacent to the carbonyl group. Treatment with excess formaldehyde (HCHO) and NaOH under heating conditions results in complete cross-aldol condensation at all available α -positions, followed by a Cannizzaro reaction. 2. Acetal/Ketal Formation: Subsequent treatment with formaldehyde in the presence of an acid catalyst (H^+) converts the resulting polyol intermediate into a cyclic acetal/dioxane ring structure.

Q12.

Answer: A

Explanation:

Cumene undergoes oxidation followed by acid hydrolysis to form phenol (*P*). Phenol reacts with chloroform and sodium hydroxide via the Reimer-Tiemann reaction to give salicylaldehyde as the major product (*Q*, *o*-hydroxybenzaldehyde) and *p*-hydroxybenzaldehyde (*R*). Compound *Q* gives a characteristic coloration with FeCl_3 due to the phenolic group and reacts with 2,4-DNP (via its derivativeS) to form a colored precipitate because it contains a carbonyl group.

Q13.

Answer: D

Explanation:

Phenylacetylene undergoes acid-catalyzed hydration to yield acetophenone ($\text{C}_8\text{H}_8\text{O}$). Nucleophilic addition of ethylmagnesium bromide followed by acid-catalyzed dehydration forms an alkene isomer with the correct carbon skeleton corresponding to option D.

Q14.

Answer: A

Explanation:

The given reactant is a dicarbonyl compound featuring a cyclic ketone and a methyl ketone group, which undergoes an intramolecular aldol condensation upon treatment with aqueous base followed by acid and heat. The more acidic α -hydrogen gets abstracted to form the more stable enolate, which attacks the other carbonyl carbon to form a stable fused-ring system (Robinson annulation / intramolecular aldol condensation). Subsequent dehydration yields the α, β -unsaturated carbonyl compound as the major product shown in option A.

Q15.

Answer: B

Explanation:

1. Phenylacetylene (C_8H_6) undergoes partial catalytic hydrogenation with Pd-BaSO_4 (Lindlar's catalyst) to form styrene (C_8H_8). 2. Styrene then undergoes hydroboration-oxidation (B_2H_6 followed by $\text{H}_2\text{O}_2/\text{NaOH}$) via anti-Markovnikov hydration to yield 1-phenylethanol as Compound X.

Q16.

Answer: D

Explanation:

The starting material contains both a primary alkyl chloride and a methyl ketone group. When treated with methylmagnesium bromide (CH_3MgBr), the Grignard reagent first attacks the more reactive carbonyl carbon of the ketone to form a tertiary alkoxide intermediate. Upon subsequent workup with aqueous acid, the resulting tertiary alcohol undergoes an intramolecular nucleophilic substitution (or acid-catalyzed cyclization) where the newly formed hydroxyl oxygen attacks the terminal carbon bearing the chlorine atom, forming a stable cyclic ether (tetrahydrofuran or tetrahydropyran derivative) containing a methyl substituent.

Q17.

Answer: C

Explanation:

The molecular formula of a ketone with a molecular weight of 100 is $\text{C}_6\text{H}_{12}\text{O}$. There are six possible acyclic ketone isomers for this molecular formula. Reduction of a ketone with NaBH_4 yields a secondary alcohol. If the resulting carbon bearing the $-\text{OH}$ group is chiral, the product is formed as a racemic mixture. Out of the six isomers, exactly five generate a chiral center upon reduction and yield a racemic product, while one symmetric isomer does not form a chiral carbon.

Q18.

Answer: A

Explanation:

The reaction sequence involves the formation of a cyclic dione compound *V* from precursor *Q* via reduction, followed by a Friedel-Crafts acylation with benzene yielding a keto-derivative, and subsequent Clemmensen reduction to give compound *W*. Based on structural correlation and the carbon skeleton, option A correctly identifies both compounds.

Q19.

Answer: B

Explanation:

Hydrolysis of the given polyketone/anhydride-like polycyclic system followed by oxidative ozonolysis cleaves double bonds and ring systems, ultimately generating dicarboxylic acids containing two carboxylic acid functional groups.

Q20.

Answer: A

Explanation:

The reaction sequence begins with a nucleophilic addition of cyanide ion (CN^-) to the carbonyl group of butan-2-one ($CH_3 - CH_2 - CO - CH_3$) to form a cyanohydrin intermediate G ($CH_3 - CH_2 - C(OH)(CH_3) - CN$). Subsequent treatment with 95% H_2SO_4 and heat induces acid-catalyzed dehydration alongside the hydrolysis of the cyano group into a carboxylic acid group, yielding α, β -unsaturated carboxylic acid as the major product H .

Q21.

Answer: 4

Explanation:

Heating β -dicarboxylic acids (or substituted malonic acid derivatives) leads to decarboxylation. In both reactions, the heating causes loss of CO_2 from the geminal dicarboxylic acid / β -carboxy groups. Counting the remaining carbonyl ($> C = O$) groups in the major organic products X and Y yields 1 and 3 respectively, giving a total sum of 4.

Q22.

Answer: 2

Explanation:

The reaction sequence involves the oxidation and structural modification of an organic substrate. Upon completing the reaction steps leading to compounds S and T , each of the final major products contains a specific functional group (such as a hydroxyl or carbonyl group accounting for one oxygen atom each). Summing the oxygen atoms in both S and T yields $1 + 1 = 2$.

Q23.

Answer: 93018

Explanation:

The polymer U (PHBV) is formed via the condensation copolymerization of 3-hydroxybutanoic acid (Q) and 3-hydroxypentanoic acid (R). During the polymerization process involving 500 moles of Q and 500 moles of R , a total of 999 moles of water molecules are eliminated. The total molecular weight is calculated by summing the masses of the reactant monomers and subtracting the mass of the eliminated water molecules.

Q24.

Answer: 18

Explanation:

Acetaldehyde undergoes aldol condensation reactions with excess formaldehyde in the presence of concentrated NaOH to yield pentaerythritol (P) and sodium formate (Q). Compound P , a polyol containing four primary hydroxyl groups, reacts with excess cyclohexanone under acid catalysis (PTSA) to form a cyclic acetal/ketal derivative (R). Summing the methylene groups and oxygen atoms in the structure of R gives $14 + 4 = 18$.

Q25.

Answer: 4

Explanation:

All four given reactions are standard synthetic methods for the preparation of benzaldehyde: 1. Gattermann-Koch reaction (I) 2. Hydrolysis of benzal chloride (II) 3. Rosenmund reduction (III) 4. Reduction of an ester (methyl benzoate) using DIBAL-H (IV)

Q26.

Answer: A

Explanation:

Substituting $t = x^2 \Rightarrow dt = 2x dx$ converts the integrand into partial fractions. Integrating yields $\log_e(x^2 + 2) - \log_e(x^2 + 3) + C$. Using $f(1)$ to evaluate $C = 0$, substituting $x = 2$ gives $\log_e 6 - \log_e 7$.

Q27.

Answer: B

Explanation:

Rewrite the integrand using derivative adjustment for $x \cot x - 1$ and apply integration by parts with $u = x \csc x$ and $dv = \frac{x \csc^2 x - \cot x}{(x \cot x - 1)^2} dx$. Evaluating at $x = \frac{\pi}{4}$ with $C = 0$ yields Option A.

Q28.

Answer: A

Explanation:

Integrating $\int \sec^2 x (\sin x)^{-2024} dx$ by parts gives $I(x) = \frac{\tan x}{\sin^{2024} x} + C$. Using $I\left(\frac{\pi}{4}\right) = 2^{1012}$ determines $C = 0$. Evaluating $I\left(\frac{\pi}{3}\right)$ and $I\left(\frac{\pi}{6}\right)$ yields $3^{1011} I\left(\frac{\pi}{3}\right) - I\left(\frac{\pi}{6}\right) = 0$.

Q29.

Answer: B

Explanation:

The derivative of the denominator $x \cos x - \sin x$ is $-x \sin x$, so the integrand can be split as $(x \csc x) \cdot \frac{x \sin x}{(x \cos x - \sin x)^2}$, which is of the form $\int u dv$ with $v = \frac{1}{x \cos x - \sin x}$. Integration by parts then leaves $\int \csc^2 x dx$, giving $\frac{x \csc x}{x \cos x - \sin x} - \cot x + C$.

Q30.

Answer: D

Explanation:

Substituting $t = \log_e x$ converts the integral into $\int e^t \sin t dt$, which is evaluated by applying integration by parts twice; the original integral reappears and is solved algebraically, giving $\frac{x}{2} [\sin(\log_e x) - \cos(\log_e x)] + C$.

Q31.

Answer: C

Explanation:

Since the limits satisfy $a + b = \frac{\pi}{12} + \frac{\pi}{6} = \frac{\pi}{4}$, applying King's property

$\int_a^b f(x) dx = \int_a^b f(a + b - x) dx$ turns $\tan 2x$ into $\cot 2x$; adding the two forms of the integral cancels the square root entirely, leaving half the length of the interval.

Q32.

Answer: C

Explanation:

Because $\sin x$ is an odd function, replacing x by $-x$ gives a companion integrand whose sum with the original cancels the exponential term completely:

$f(x) + f(-x) = \sin^2 x$. Using $\int_{-a}^a f(x) dx = \int_0^a [f(x) + f(-x)] dx$ reduces the problem to $\int_0^{\pi/2} \sin^2 x dx = \frac{\pi}{4}$.

Q33.

Answer: C

Explanation:

The numerator $\sin^2 x$ is even while the exponential term satisfies

$\frac{1}{1 + 5^x} + \frac{1}{1 + 5^{-x}} = 1$, so using $\int_{-a}^a f(x) dx = \int_0^a [f(x) + f(-x)] dx$ the denominator cancels out and the integral reduces to $\int_0^{\pi} \sin^2 x dx = \frac{\pi}{2}$.

Q34.

Answer: C

Explanation:

The cubic inside the root satisfies $p(1 - x) = -p(x)$, i.e.

$4(1 - x)^3 - 6(1 - x)^2 + 4(1 - x) - 1 = -(4x^3 - 6x^2 + 4x - 1)$. Hence the integrand $f(x) = \sqrt[3]{p(x)}$ obeys $f(1 - x) = -f(x)$, and by the property $\int_0^1 f(x) dx = \int_0^1 f(1 - x) dx$ the integral equals its own negative, forcing it to be 0.

Q35.

Answer: A

Explanation:

Splitting the integrand, the term $\frac{x}{1 + \cos^2 x}$ is odd and vanishes over $[-\pi, \pi]$, while $\frac{x \sin x}{1 + \cos^2 x}$ is even, doubling to $[0, \pi]$. King's property on $[0, \pi]$ then removes x , leaving an arctan-type integral whose value gives $\frac{\pi^2}{2}$.

Q36.

Answer: A

Explanation:

The numerator can be rewritten as $(x + \sin x) - x(1 + \cos x)$, which splits the fraction into $\frac{1}{x} - \frac{1 + \cos x}{x + \sin x}$. Each piece is of the form $\frac{f'}{f}$, so the integral becomes a difference of logarithms that combines to $\log \left| \frac{x}{x + \sin x} \right| + c$.

Q37.

Answer: B

Explanation:

The expression under the square root collapses to a perfect square:

$1 + 2 \tan^2 x + 2 \tan x \sec x = \frac{(1 + \sin x)^2}{\cos^2 x}$, so the integrand becomes $\sec x + \tan x$. Integrating and combining the logarithms yields $-\ln |1 - \sin x| + c = -2 \ln \left| \cos \frac{x}{2} - \sin \frac{x}{2} \right| + c$.

Q38.

Answer: A

Explanation:

Splitting the integrand, the term $\frac{e^{\tan x} \sin 2x}{\cos^2 x}$ simplifies to $2 \tan x e^{\tan x}$, which is exactly the leftover term produced when integrating $(2 \ln \sec x) e^{\tan x} \sec^2 x$ by parts (with $v = e^{\tan x}$). The two cancel, leaving $2e^{\tan x} \ln(\sec x) + c$.

Q39.

Answer: B

Explanation:

The half-angle (Weierstrass) substitution $t = \tan \frac{x}{2}$ turns $1 - \cos x + \sin x$ into $\frac{2t(1+t)}{1+t^2}$ and dx into $\frac{2 dt}{1+t^2}$, so the integral becomes $\int \frac{dt}{t(1+t)}$. Partial fractions then give $\ln \left| \frac{t}{1+t} \right| + c$, hence $f(x) = \frac{\tan \frac{x}{2}}{1 + \tan \frac{x}{2}}$.

Q40.

Answer: B

Explanation:

The quadratic $3 + x - x^2$ is unchanged under $x \rightarrow 1 - x$, while the exponent satisfies $1 - 2(1 - x) = -(1 - 2x)$. Adding the integral to its King's-property twin cancels the exponential factor, leaving $2I = \int_0^1 \frac{dx}{3 + x - x^2}$, a standard $\int \frac{dx}{a^2 - u^2}$ logarithmic integral.

Q41.

Answer: B

Explanation:

Shifting the variable to the midpoint of the limits, $t = x - 3$, converts the product into $(t+2)(t+1)(t-1)(t-2) = (t^2-1)(t^2-4) = t^4 - 5t^2 + 4$, which is an even function over the symmetric interval $[-2, 2]$; hence the integral equals twice the half-range integral, giving $\frac{32}{15}$.

Q42.

Answer: B

Explanation:

Substituting $x = \sin \theta$ turns $(1 - x^2)^{3/2}$ into $\cos^3 \theta$ and $\cos^{-1}(\sin \theta)$ into $\frac{\pi}{2} - \theta$, reducing the integral to $\int_0^{\pi/4} \left(\frac{\pi}{2} - \theta \right) \sec^2 \theta d\theta$, which by parts gives $\frac{\pi}{4} + \frac{1}{2} \log 2$.

Q43.

Answer: A

Explanation:

Replacing x by $-x$ interchanges the two square roots, since $\sin(-x) = -\sin x$ while $\sin^2(-x) = \sin^2 x$; hence the integrand is an odd function, and its integral over the symmetric interval $\left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$ vanishes.

Q44.

Answer: C

Explanation:

Under $x \rightarrow \frac{\pi}{2} - x$ the roles of $\sin x$ and $\cos x$ swap, so the integral equals its companion with $\cos^{3/2} x$ on top; adding the two forms gives $\int_0^{\pi/2} 1 \, dx = \frac{\pi}{2}$, hence the integral is half of that, $\frac{\pi}{4}$.

Q45.

Answer: A

Explanation:

Writing $\frac{1}{1 + \tan \theta} = \frac{\cos \theta}{\cos \theta + \sin \theta}$ and splitting the numerator as $\cos \theta = \frac{1}{2}[(\cos \theta + \sin \theta) + (\cos \theta - \sin \theta)]$ gives a constant term plus a $\frac{f'}{f}$ term, yielding $\frac{\pi}{8} + \frac{1}{4} \log 2$.

Q46.

Answer: 3

Explanation:

Multiplying numerator and denominator by $\cos x$ gives $\frac{3 \cos x - \sin x}{2 \cos x + \sin x}$; writing the numerator as $A(2 \cos x + \sin x) + B(\cos x - 2 \sin x)$ (denominator plus its derivative) yields $A = B = 1$, so the integral is $x + \log_e |\sin x + 2 \cos x| + C$, giving $\alpha + \frac{\gamma}{\beta} = 1 + 2 = 3$.

Q47.

Answer: 4

Explanation:

Using $\sin^6 x + \cos^6 x = 1 - 3 \sin^2 x \cos^2 x = \frac{5}{8} + \frac{3}{8} \cos 4x$, the cosine term integrates to zero over $[0, 10\pi]$ (a whole number of its periods), leaving $\frac{5}{8} \cdot 10\pi = \frac{25}{4} \pi$.

Q48.

Answer: 49

Explanation:

Since $48x^2 \sin^2 x$ is even, the factor $\frac{1}{1 + e^x}$ can be eliminated by the substitution $x \rightarrow -x$ and adding, reducing the integral to $\int_0^{\pi/2} 48x^2 \sin^2 x \, dx$. Two integrations by parts give $\pi^3 + 6\pi = \pi(\pi^2 + 6)$, so $\alpha = 1$, $\beta = 6$ and $(\alpha + \beta)^2 = 49$.

Q49.

Answer: 1

Explanation:

The half-angle identity $1 - \cos x = 2 \sin^2 \frac{x}{2}$ converts the integrand into $\frac{1}{2} \csc^2 \frac{x}{2}$, whose antiderivative is $-\cot \frac{x}{2}$; evaluating between $\frac{\pi}{2}$ and π gives 1.

Q50.

Answer: 4

Explanation:

Under $x \rightarrow \frac{\pi}{2} - x$ the integrand becomes its companion with $\cos^5 x$ on top; adding the two forms gives $\int_0^{\pi/2} 1 \, dx = \frac{\pi}{2}$, so the integral is $\frac{\pi}{4}$, i.e. $\frac{\pi}{x}$ with $x = 4$.

Q51.

Answer: B

Explanation:

The Q-value of a neutron capture reaction equals the gain in binding energy, since the neutron itself has zero binding energy. From the first reaction

$$BE({}_3^7\text{Li}) = BE({}_3^6\text{Li}) + 16, \text{ and from the second}$$

$$BE({}_3^8\text{Li}) = BE({}_3^7\text{Li}) - 2 = BE({}_3^6\text{Li}) + 14. \text{ Thus}$$

$$BE({}_3^7\text{Li}) > BE({}_3^8\text{Li}) > BE({}_3^6\text{Li}), \text{ so the stability order is } X_7 > X_8 > X_6.$$

Q52.

Answer: C

Explanation:

Isobars are nuclei having the same mass number A but different atomic numbers Z . Only the pair ${}_{19}^{40}\text{K}$ and ${}_{20}^{40}\text{Ca}$ has equal mass number ($A = 40$) with different charge numbers ($Z = 19$ and $Z = 20$), so this pair constitutes isobars.

Q53.

Answer: B

Explanation:

In α -decay the α -particle carries kinetic energy $K = Q \frac{A-4}{A}$, where A is the mass number of the parent nucleus (momentum conservation splits Q between the α -particle and the daughter). Since Q is the same for both, the ratio is

$$\frac{K_A}{K_B} = \frac{204/208}{200/204} = \frac{204 \times 204}{208 \times 200} = \frac{41616}{41600} = \frac{2601}{2600}.$$

Q54.

Answer: A

Explanation:

Energy released in a nuclear reaction is the increase in total binding energy. The initial binding energy is the sum of the binding energies of deuterium and tritium. The neutron has zero binding energy. The final binding energy is that of the helium nucleus.

Q55.

Answer: B

Explanation:

A carbon-13 atom contains 6 protons and 7 neutrons. First calculate the total mass of the separate protons and neutrons. The difference between this mass and the experimental atomic mass is the mass defect.

Q56.

Answer: B

Explanation:

The binding energy is obtained from the mass defect. For an atom, it is convenient to use the hydrogen-atom mass because the electron masses then cancel automatically. First calculate the mass of the 27 hydrogen atoms and 33 neutrons separately. Their difference from the actual cobalt-60 atomic mass gives the mass defect. Then convert the mass defect into energy and divide by 60 nucleons.

Q57.

Answer: C

Explanation:

The radius of a nucleus is proportional to $A^{1/3}$. Therefore, its volume is proportional to A . Since nuclear mass is also proportional to A , the ratio of mass to volume remains approximately constant. Hence, the densities of iron-56 and carbon-12 nuclei are approximately equal, so Assertion (A) is false while Reason (R) is true.

Q58.

Answer: B

Explanation:

A is nuclear fission because a heavy nucleus splits into smaller nuclei. B and D are nuclear fusion reactions. Both have positive Q values because the products have greater total binding energy than the reactants. C is a chemical reaction because hydrogen and oxygen combine without changing their nuclei.

Q59.

Answer: B

Explanation:

In electron capture, a proton inside the nucleus captures an orbital electron and changes into a neutron. A neutrino is emitted to conserve lepton number. Therefore, the correct process is $p + e^- \rightarrow n + \nu$.

Q60.

Answer: A

Explanation:

The decay constant of n_2 is twice that of n_1 , so n_2 decays faster. After two half-lives of n_1 , one-fourth of n_1 remains, while only one-sixteenth of n_2 remains. Therefore, the ratio is $\frac{1}{4}$.

Q61.

Answer: A

Explanation:

The oxygen-16 nucleus contains 8 protons and 8 neutrons. The mass defect is the difference between the total mass of the separated nucleons and the actual nuclear mass. Thus, the binding energy is the mass defect multiplied by c^2 .

Q62.

Answer: B

Explanation:

In a nuclear reaction, both mass number and atomic number must be conserved. By comparing the total mass number and atomic number on both sides, each emitted particle R is found to have mass number 0 and atomic number 0, which corresponds to a neutron.

Q63.

Answer: B

Explanation:

The disintegration energy is obtained from the mass defect. First calculate the total mass before and after fission. Their difference is the mass defect, which is then converted into energy using $E = \Delta mc^2$.

Q64.

Answer: C

Explanation:

In 12 years, there are 3 half-lives. After 3 half-lives, the fraction remaining is $\frac{1}{8}$. Therefore, the fraction that has decayed is $1 - \frac{1}{8} = \frac{7}{8}$.

Q65.

Answer: B

Explanation:

The energy released in a nuclear reaction is obtained from the mass defect. Subtract the total mass of the products from the mass of the reactant, then multiply the mass defect by $931.5 \text{ MeV}/c^2$.

Q66.

Answer: D

Explanation:

According to Rutherford's scattering formula from the Geiger-Marsden experiment, the number of scattered α -particles $N(\theta)$ is inversely proportional to $\sin^4(\theta/2)$. As the scattering angle θ increases, $N(\theta)$ decreases very rapidly, which is correctly represented by graph D.

Q67.

Answer: C

Explanation:

Statements A, B and C are correct: cadmium absorbs neutrons and regulates the chain reaction, β^- decay converts a neutron into a proton so A stays constant while Z increases by one, and α particles ionise heavily and hence penetrate less. Statement D is wrong because a moderator slows fast neutrons down to thermal energies instead of speeding them up.

Q68.

Answer: B

Explanation:

An α particle reduces the mass number by 4 and the atomic number by 2, while e^+ emission reduces Z by 1 and each e^- (or β^-) emission increases Z by 1, with no change in A . Hence the final nucleus has $A = 236 - 4 = 232$ and $Z = 92 - 2 - 1 + 1 + 1 = 91$.

Q69.

Answer: A

Explanation:

The emission of an electron e^- together with an antineutrino $\bar{\nu}$ is β^- decay, in which a neutron changes into a proton. Hence the mass number stays at 234 while the atomic number increases by one, from 90 to 91, giving $X = {}_{91}^{234}\text{Pa}$.

Q70.

Answer: D

Explanation:

The nuclear radius follows $R = R_0 A^{1/3}$, so the ratio of radii is $\left(\frac{216}{64}\right)^{1/3} = \frac{6}{4} = \frac{3}{2}$, i.e. 3 : 2.

Q71.

Answer: 75

Explanation:

The activity after n half lives is $A = A_0(1/2)^n$. Since $1/32 = (1/2)^5$, the substance needs $n = 5$ half lives, so the required time is $t = 5 \times 15 = 75$ minutes.

Q72.

Answer: 180

Explanation:

The activity falls by a factor of 2 in every half life, so $\left(\frac{1}{2}\right)^n = \frac{1}{64}$ gives $n = 6$ half lives. Therefore the required time is $t = n \times T_{1/2} = 6 \times 30 = 180$ minutes.

Q73.

Answer: 75

Explanation:

The number of nuclei left is $1200 - 1050 = 150$, which is $\frac{1}{8} = \left(\frac{1}{2}\right)^3$ of the initial number, so 3 half lives pass and the time is $3 \times 25 = 75$ minutes.

Q74.

Answer: 75

Explanation:

After 20% decay, 80% of the nuclei remain; after 90% decay, only 10% remain. The ratio $\frac{10}{80} = \frac{1}{8} = \left(\frac{1}{2}\right)^3$ corresponds to 3 half lives, so the time between these stages is $3 \times 25 = 75$ minutes.

Q75.

Answer: 5589

Explanation:

The Q value is the mass defect converted to energy:

$$\Delta m = 226.025 - (222.016 + 4.003) = 0.006 \text{ u, so}$$

$$Q = 0.006 \times 931.5 \text{ MeV} = 5.589 \text{ MeV} = 5589 \text{ keV}.$$