Each question is worth 3 points. Mark your answers on the exam and on the scantron form.

First-order decay kinetics
\[
\ln(A/A_0) = -kt
\]
\[
\ln(A) = -kt + \ln(A_0)
\]
\[
kt_{1/2} = 0.693
\]

\[
\left[H_3O^+\right][OH^-] = K_W = K_aK_b = 10^{-14}
\]
\[
pH + pOH = 14.00
\]
\[
pH = -\log[H_3O^+]
\]
\[
pOH = -\log[OH^-]
\]

\[
E = \Delta mc^2
\]
\[
c = 3.0 \times 10^8 \text{ m/s}
\]

\[
p = 10^{-12}
\]
\[
n = 10^{-9}
\]
\[
u = 10^{-6}
\]
\[
m = 10^{-3}
\]
\[
c = 10^{-2}
\]
\[
k = 10^3
\]
\[
M = 10^6
\]
\[
G = 10^9
\]
1. Alpha particles are identical to
   A. protons.
   B. helium atoms.
   C. hydrogen atoms.
   D. helium nuclei.
   E. electrons.

2. How many neutrons and protons (nucleons) does an atom with the symbol $^{33}_{16}$S have?
   A. 33
   B. 16
   C. 49
   D. 16
   E. None of these.

3. When atoms of beryllium-9 are bombarded with alpha particles, neutrons are produced. What new isotope is also formed?
   \[ ^4_2\text{He} + ^9_4\text{Be} \rightarrow ^1_0\text{n} + ____ \]
   A. $^{12}_6\text{C}$
   B. $^{5}_3\text{Li}$
   C. $^{8}_3\text{Li}$
   D. $^{10}_5\text{B}$
   E. $^{12}_5\text{B}$
4. What is the missing symbol in this plutonium fission reaction?

\[ ^{239}_{94}\text{Pu} + ^{1}_{0}\text{n} \rightarrow _____ + ^{91}_{38}\text{Sr} + 3^{1}_{0}\text{n} \]

A. $^{148}_{56}\text{Ba}$
B. $^{0}_{-1}\beta$
C. $^{143}_{54}\text{Xe}$
D. $^{91}_{38}\text{Sr}$
E. $^{146}_{56}\text{Ba}$

5. A typical radius of an atomic nucleus is about

A. 100 µm
B. 5000 mm
C. 100 nm
D. $5\times10^{-3}$ pm
E. 500 pm

6. What is the nuclear binding energy per nucleon, in joules, for $^{25}_{12}\text{Mg}$ (atomic mass 24.985839 amu). [Data: $^{1}_{0}\text{n}$ (atomic mass) = 1.008665 amu; $^{1}_{1}\text{p}$ (mass) = 1.007825 amu; 1 kg = $6.022\times10^{26}$ amu; $c = 3.00\times10^{8}$ m/s, 1 amu = $1.661\times10^{-27}$ kg]

A. 0.22076 J/nucleon
B. $3.30\times10^{-11}$ J/nucleon
C. $1.32\times10^{-12}$ J/nucleon
D. 0.999 J/nucleon
E. None of these.

7. What fraction of radioactive atoms remains in a sample after six half-lives?

A. zero
B. 1/6
C. 1/16
D. 1/32
E. 1/64
8. A rock contains 0.37 mg of Pb-206 and 0.95 mg of U-238. The half-life of the decay series $^{238}\text{U} \rightarrow ^{206}\text{Pb}$ is $4.5 \times 10^9$ yr. Assuming no Pb-206 was present in the rock initially, how old is the rock?

A. $1.7 \times 10^9$ yr
B. $5.2 \times 10^9$ yr
C. $2.7 \times 10^6$ yr
D. $4.5 \times 10^9$ yr
E. $2.4 \times 10^9$ yr

9. Charcoal found under a stone at Stonehenge, England, has a carbon-14 activity that is 0.60 that of new wood. How old is the charcoal? (The half-life of carbon-14 is 5,730 years.)

A. Less than 5,730 yr
B. Between 5,730 and 11,460 yr
C. Between 11,460 and 17,190 yr
D. More than 17,190 yr

10. The Rb-87/Sr-87 method of dating rocks is often used by geologists:

$$^{87}\text{Rb} \rightarrow ^{87}\text{Sr} + ^0\text{β} \quad t_{1/2} = 6.0 \times 10^{10} \text{ yr}$$

Estimate the age of a rock sample in which the present-day mole ratio of Rb-87 to Sr-87 is 36:1.

A. $2.4 \times 10^9$ yr
B. $1.7 \times 10^9$ yr
C. $3.1 \times 10^{11}$ yr
D. $4.1 \times 10^{-11}$ yr
E. $3.6 \times 10^{11}$ yr
11. Which is the formula for the hydronium ion?

A. OH$^-$
B. H$_2$O
C. H$_3$O$^+$
D. H$_3$O$^-$
E. H$_2$O$^+$

12. In the reaction HSO$_4^-$ (aq) + OH$^-$ (aq) $\rightarrow$ SO$_4^{2-}$ (aq) + H$_2$O(l), the conjugate acid-base pairs are

| Row 1 | HSO$_4^-$ and SO$_4^{2-}$; H$_2$O and OH$^-$.
| Row 2 | HSO$_4^-$ and H$_2$O$^+$; SO$_4^{2-}$ and OH$^-$.
| Row 3 | HSO$_4^-$ and OH$^-$; SO$_4^{2-}$ and H$_2$O.
| Row 4 | HSO$_4^-$ and H$_2$O; OH$^-$ and SO$_4^{2-}$.
| Row 5 | HSO$_4^-$ and OH$^-$; SO$_4^{2-}$ and H$_3$O$^+$.

A. Row 1
B. Row 2
C. Row 3
D. Row 4
E. Row 5

13. Identify the conjugate base of HSO$_4^-$ in the reaction

H$_2$PO$_4^-$ + HSO$_4^-$ $\rightarrow$ H$_3$PO$_4$ + SO$_4^{2-}$

A. H$_2$PO$_4^-$
B. H$_2$SO$_4$
C. H$_2$O
D. H$_3$PO$_4$
E. SO$_4^{2-}$

14. Which one of these statements about strong acids is true?

A. All strong acids have H atoms bonded to electronegative oxygen atoms.
B. Strong acids are 100% ionized in water.
C. The conjugate base of a strong acid is itself a strong base.
D. Strong acids are very concentrated acids.
E. Strong acids produce solutions with a higher pH than weak acids.
15. One liter of an aqueous solution contains \(6.02 \times 10^{21}\) \(\text{H}_3\text{O}^+\) ions. Therefore, its \(\text{H}_3\text{O}^+\) ion concentration is

A. 0.0100 mole per liter.  
B. 0.100 mole per liter.  
C. 1.00 mole per liter.  
D. \(6.02 \times 10^{21}\) mole per liter.  
E. \(6.02 \times 10^{23}\) mole per liter

16. What is the concentration of \(\text{H}^+\) in a 2.5 M HCl solution?

A. 0  
B. 1.3 M  
C. 2.5 M  
D. 5.0 M  
E. 10.0 M

17. The \(\text{OH}^-\) concentration in a \(2.5 \times 10^-3\) M \(\text{Ba(OH)}_2\) solution is

A. \(4.0 \times 10^{-12}\) M.  
B. \(2.5 \times 10^{-3}\) M.  
C. \(5.0 \times 10^{-3}\) M.  
D. \(1.2 \times 10^{-2}\) M.  
E. \(0.025\) M.

18. Calculate the \(\text{H}^+\) ion concentration in a \(8.8 \times 10^{-4}\) M \(\text{Ca(OH)}_2\) solution.

A. \(8.8 \times 10^{-4}\) M  
B. \(1.8 \times 10^{-3}\) M  
C. \(2.2 \times 10^{-11}\) M  
D. \(1.1 \times 10^{-11}\) M  
E. \(5.7 \times 10^{-12}\) M

19. A 0.14 M HNO\(_2\) solution is 5.7% ionized. Calculate the \(\text{H}^+\) ion concentration.

A. \(8.0 \times 10^{-3}\) M  
B. \(0.057\) M  
C. \(0.13\) M  
D. \(0.14\) M  
E. \(0.80\) M
20. A 0.10 M NH₃ solution is 1.3% ionized. Calculate the H⁺ ion concentration.

\[ \text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^- \]

A. \(1.3 \times 10^{-3}\) M
B. \(7.7 \times 10^{-2}\) M
C. \(7.7 \times 10^{-12}\) M
D. 0.13 M
E. 0.10 M

21. Calculate the H₃O⁺ ion concentration in lemon juice having a pH of 2.4.

A. \(4.0 \times 10^{-2}\) M
B. 250 M
C. 0.38 M
D. \(4.0 \times 10^{-3}\) M
E. 12 M

22. Calculate the pH of a \(6.71 \times 10^{-2}\) M NaOH solution.

A. 12.83
B. 2.17
C. 11.82
D. 6.71
E. 1.17

23. What is the pH of a 0.001 M Ca(OH)₂ solution?

A. 3.0
B. 11.0
C. 2.7
D. 17.0
E. 11.3

24. The pOH of a solution is 9.60. Calculate the hydrogen ion concentration in this solution.

A. \(2.5 \times 10^{-10}\) M
B. \(6.0 \times 10^{-9}\) M
C. \(4.0 \times 10^{-5}\) M
D. \(2.4 \times 10^{-4}\) M
E. \(1.0 \times 10^{-14}\) M
25. Which solution will have the lowest pH?

A. 0.10 M HCN
B. 0.10 M HNO₃
C. 0.10 M NaCl
D. 0.10 M H₂CO₃
E. 0.10 M NaOH

26. Which one of these responses is true with regard to a 0.1 M solution of a weak acid HA?

A. [H⁺] > [A⁻]
B. pH = 1.0
C. [H⁺] < [A⁻]
D. pH > 1.0
E. [OH⁻] > [H⁺]

27. Acid strength increases in the series: HCN < HF < HSO₄⁻. Which of these species is the strongest base?

A. H₂SO₄
B. SO₄²⁻
C. F⁻
D. CN⁻
E. HSO₄⁻

28. Arrange the acids HOCl, HClO₃, and HClO₂ in order of increasing acid strength.

A. HOCl < HClO₃ < HClO₂
B. HOCl < HClO₂ < HClO₃
C. HClO₂ < HOCl < HClO₃
D. HClO₃ < HOCl < HClO₂
E. HClO₃ < HClO₂ < HOCl

29. Which one of these net ionic equations represents the reaction of a strong acid with a weak base?

A. H⁺(aq) + OH⁻(aq) → H₂O(aq)
B. H⁺(aq) + CH₃NH₂(aq) → CH₃NH₃⁺(aq)
C. OH⁻(aq) + HCN(aq) → H₂O(aq) + CN⁻(aq)
D. HCN(aq) + CH₃NH₂(aq) → CH₃NH₃⁺(aq) + CN⁻(aq)
30. Which of these species will act as a Lewis acid?
   A. NH₃
   B. NH₄⁺
   C. H₂O
   D. BF₃
   E. F⁻

31. In the reaction CaO(s) + SO₂(g) → CaSO₃(s),
   A. O²⁻ acts as a Lewis base, and SO₂ acts as a Lewis acid.
   B. Ca²⁺ acts as a Lewis base, and SO₄²⁻ acts as a Lewis acid.
   C. SO₄²⁻ acts as a Lewis base, and SO₂ acts as a Lewis acid.
   D. SO₂ acts as a Lewis base, and O²⁻ acts as a Lewis acid.
   E. SO₂ acts as a Lewis base, and Ca²⁺ acts as a Lewis acid.

32. Which one of the following salts will form an acidic solution on dissolving in water?
   A. LiBr
   B. NaF
   C. KOH
   D. FeCl₃
   E. NaCN

33. What mass of sodium nitrite must be added to 350. mL of water to give a solution with pH = 8.40? [Kₐ(HNO₂) = 5.6 × 10⁻⁴]
   A. 68 g
   B. 1.7 × 10⁻⁴ g
   C. 0.039 g
   D. 8.3 g
   E. 24 g
ANSWERS
1  D
2  A
3  A
4  E
5  D
6  C
7  E
8  E
9  A
10 A
11 C
12 A
13 E
14 B
15 A
16 C
17 C
18 E
19 A
20 C
21 D
22 A
23 E
24 C
25 B
26 D
27 D
28 B
29 B
30 D
31 A
32 D
33 D