



## Information

For the reaction  $aA + bB = cC + dD$ ,  $rate = -\frac{1}{a} \frac{\Delta[A]}{\Delta t} = -\frac{1}{b} \frac{\Delta[B]}{\Delta t} = +\frac{1}{c} \frac{\Delta[C]}{\Delta t} + \frac{1}{d} \frac{\Delta[D]}{\Delta t}$

$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$ , 1<sup>st</sup> order reactions:  $\ln[A]_t = -kt + \ln[A]_0$ ,  $t_{1/2} = 0.693/k$

2<sup>nd</sup> order reactions:  $\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$ ,  $t_{1/2} = \frac{1}{k[A]_0}$ , Arrhenius:  $\ln k = -(E_a/RT) + \ln A$

$\ln(k_1/k_2) = E_a/R(1/T_2 - 1/T_1)$ ,  $R = 8.314 \text{ J/(mol}\cdot\text{K)}$ ,  $K_p = K_c(RT)^{\Delta n}$ ,  $R = 0.0821 \text{ L}\cdot\text{atm/(mol}\cdot\text{K)}$

$K_a = \frac{[H^+][X^-]}{[HX]}$ ,  $K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$ ,  $K_a \times K_b = K_w$ ,  $pK_a + pK_b = pK_w = 14.00$ ;

For the reaction  $aA + bB = cC + dD$

$$\Delta S^\circ = [cS^\circ(C) + dS^\circ(D)] - [aS^\circ(A) + bS^\circ(B)]$$

$$\Delta G^\circ = [c\Delta G_f^\circ(C) + d\Delta G_f^\circ(D)] - [a\Delta G_f^\circ(A) + b\Delta G_f^\circ(B)]$$

$$\Delta G = \Delta H - T\Delta S, \Delta G = \Delta G^\circ + RT \ln Q, \Delta G^\circ = -RT \ln K, K = e^{-\Delta G^\circ / RT}$$

$$pH = pK_a + \log\left(\frac{[\text{base}]}{[\text{acid}]}\right), \text{CaF}_2 \rightarrow \text{Ca}^{+2} + 2\text{F}^- \quad K_{sp} = [\text{Ca}^{2+}][\text{F}^-]^2$$

$$E_{cell}^\circ = E_{red}^\circ(\text{cathode}) - E_{red}^\circ(\text{anode})$$

$$E_t^\circ = E_{red}^\circ(\text{reduction...process}) - E_{red}^\circ(\text{oxidation...process})$$

$$\Delta G = -nFE, \quad 1F = 96,500 \text{ C/mol} = 96,500 \text{ J/V}\cdot\text{mol}$$

$$E = E^\circ - \frac{0.0592V}{n} \log Q, \quad w = nFE_{ext}, \quad 1W = 1J/s, \quad \text{Rate} = kN,$$

$$\ln \frac{N_t}{N_0} = -kt, \quad k = \frac{0.693}{t_{1/2}}, \quad \Delta E = c^2 \Delta m, \quad 1J = 1kg \frac{m^2}{s^2}, \quad 1\text{amu} = 1.6605 \times 10^{-24} \text{ g}$$

$$N = 6.02214 \times 10^{23} / \text{mol}, \quad c = 2.9979 \times 10^8 \text{ m/s}$$

## New Material

(1) Which one of the following metallic elements is most likely to be found as the free metal in nature?

- a) Ca
  - b) Au
  - c) Al
  - d) Fe
  - e) Li
- 

(2) What is the purpose of a converter in steel production?

- a) to reduce the iron in the ore to elemental
  - b) to remove impurity elements by oxidation
  - c) to allow the formation of phosphides within the metal for added corrosion resistance
  - d) to allow the addition of nitrogen for increased strength
  - e) to allow slow solidification of the molten metal so it will purify as it crystalizes
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(3) Steel is

- a) an alloy of iron
  - b) pure iron
  - c) oxidized iron
  - d) a mixture of iron and silver
  - e) a liquid at room temperature
- 

(4) Why is the anhydrous aluminum oxide dissolved in molten cryolite rather than simply melted?

- a) the cryolite actually provides the aluminum that is to be reduced
- b) the cryolite provides a source of sodium ions
- c) the melting point of pure, anhydrous aluminum oxide is too high
- d) in pure, molten  $\text{Al}_2\text{O}_3$ , the aluminum would be oxidized rather than reduced
- e) the cryolite provides the necessary fluoride ions

(5) What is the oxidation number of chromium in  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ ?

a) -3

b) +3

c) +2

d) -2

e) 0

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(6) How many d electrons are in the cobalt ion of  $\text{K}_3[\text{CoCN}_6]$ ?

a) 3

b) 5

c) 6

d) 7

e) 4

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(7) How many bonds can ethylenediamine (en) form to a metal ion?

a) 1

b) 2

c) 3

d) 4

e) 6

---

(8) Which one of the following is the correct formula for potassium diaquatetrachloromolybdate (III)?

a)  $\text{K}_2[\text{Mo}(\text{H}_2\text{O})_2\text{Cl}_4]$

b)  $\text{K}[\text{Mo}(\text{H}_2\text{O})\text{Cl}_2]\text{Cl}_2$

c)  $\text{K}[\text{Mo}(\text{H}_2\text{O})_2\text{Cl}_4]$

d)  $[\text{Mo}(\text{H}_2\text{O})_2]\text{Cl}_4$

e)  $\text{K}_3[\text{Mo}(\text{H}_2\text{O})_2\text{Cl}_4]$

(9) A geometrical isomer with like groups located on opposite sides of the metal atom is denoted with the prefix

- a) cis-
- b) trans-**
- c) bis-
- d) tetrakis-
- e) d-

(10) How many isomers exist for the octahedral complex ion  $[\text{Co}(\text{NH}_3)_4\text{F}_2]^+$ ?

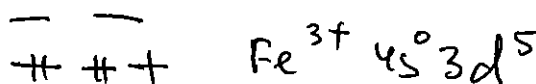
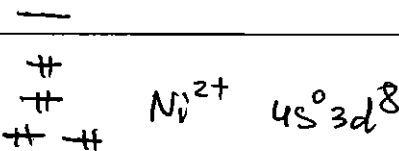
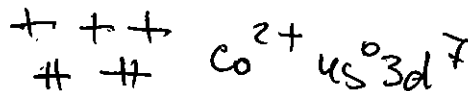
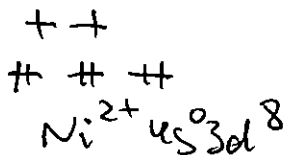
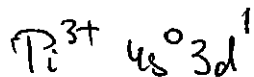
- a) 1
- b) 2**
- c) 3
- d) 4
- e) 5

(11) Which one of the following species is paramagnetic?

- a)  $\text{Na}^+$
- b)  $\text{Cr}^{3+}$**
- c)  $\text{Zn}^{2+}$
- d)  $\text{Al}^{3+}$
- e) Zn

(12) Which complex below has two unpaired electrons?

- a) square-planar  $[\text{Ni}(\text{CN})_4]^{2-}$
- b) low-spin octahedral  $[\text{Fe}(\text{CN})_6]^{3-}$
- c) tetrahedral  $[\text{CoCl}_4]^{2-}$
- d) octahedral  $[\text{Ni}(\text{NH}_3)_6]^{2+}$**
- e) octahedral  $[\text{Ti}(\text{NH}_3)_6]^{3+}$



(13) Hydrocarbons containing only single bonds between the carbon atoms are called \_\_\_\_\_

- a) alkenes
  - b) alkynes
  - c) aromatics
  - d) alkanes
  - e) ketones
- 

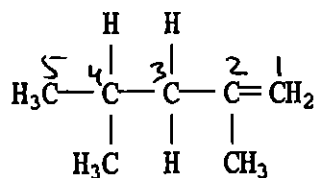
(14) The molecular geometry of each carbon atom in an alkane is \_\_\_\_\_

- a) octahedral
  - b) square planar
  - c) trigonal planar
  - d) tetrahedral
  - e) trigonal pyramidal
- 

(15) Alkynes have the general formula:

- a)  $C_nH_{2n}$
  - b)  $C_nH_{2n-2}$
  - c)  $C_nH_{2n+2}$
  - d)  $C_nH_n$
  - e)  $C_{2n}H_n$
- 

(16) What is the name of the compound below?



- a) 2,4-methylbutene
- b) 2,5-dimethylpentane
- c) 2,4-ethylbutene
- d) 2,4-dimethyl-1-pentene
- e) 2,4-dimethyl-4-pentene

(17) What is the general formula for a ketone?

- a) R-O-R'
  - b) R-CO-R'
  - c) R-CO-OH
  - d) R-OH
  - e) R-CO-H
- 

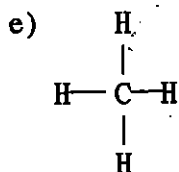
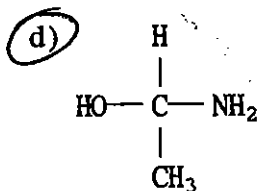
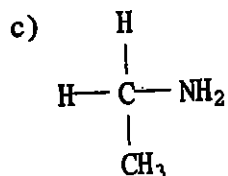
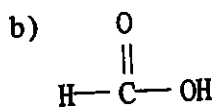
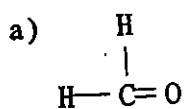
(18) The general formula of an aldehyde is \_\_\_\_\_.

- a) R-O-R'
  - b) R-CO-R'
  - c) R-CO-OH
  - d) R-CO-H
  - e) R-CO-OR'
- 

(19) The general formula of a carboxylic acid is

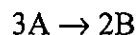
- a) R-O-R'
  - b) R-CO-R'
  - c) R-CO-OH
  - d) R-H
  - e) R-CO-OR'
- 

(20) Which one of the following molecules is chiral



**Comprehensive Review Materials:**

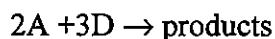
(21) Consider the following reaction:



The average rate of appearance of B is given by  $\Delta[B]/\Delta t$ . How is the average rate of appearance of B related to the average rate of disappearance of A?

- a)  $+2\Delta[A]/\Delta t$
- b)  $-2\Delta[A]/3\Delta t$
- c)  $-3\Delta[A]/2\Delta t$
- d)  $-\Delta[A]/\Delta t$
- e)  $+3\Delta[A]/2\Delta t$

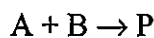
(22) If the reaction



is first order in A and second order in D, then the rate law will be rate = \_\_\_\_\_

- a)  $k[A][D]$
- b)  $k[A]^2[D]^3$
- c)  $k[A][D]^2$
- d)  $k[A]^2[D]$
- e)  $k[A]^2[D]^2$

(23) Use the information below to determine the overall order of the reaction.



Experiment Number	[A] (M)	[B] (M)	Initial Rate (M/s)
1	0.273	0.763	2.83
2	0.273	1.526	2.83
3	0.819	0.763	25.47

a) 1  
 b) 2  
 c) 3  
 d) 4  
 e) 0

$$\frac{\text{rate}_1}{\text{rate}_2} = \frac{k[A_1]^n[B_1]^m}{k[A_2]^n[B_2]^m} ; 1 = \frac{[0.76]^m}{[1.526]^m} \quad m = 0$$

$$\frac{\text{rate}_1}{\text{rate}_3} = \frac{k[A_1]^n[B_1]^m}{k[A_3]^n[B_3]^m} ; 0.11 = \frac{[A_1]^n}{[A_3]^n} = [0.333]^n$$

$$n = 2$$

$$\text{rate} = k[A]^2[B]^0$$

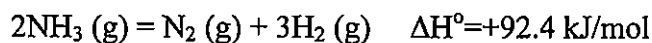
(24) The equilibrium expression

$$K_c = \frac{[H_2]^2 [O_2]}{[H_2O]^2}$$

is the equilibrium constant expression for the reaction \_\_\_\_\_

- a)  $2H_2(g) + O_2(g) = 2H_2O(g)$
  - b)  $H_2O(g) = H_2(g) + 1/2O_2(g)$
  - c)  $H_2O(g) = 2H(g) + O(g)$
  - d)  $2H_2O(g) = 2H_2(g) + O_2(g)$
  - e)  $H_2(g) + 1/2O_2(g) = H_2O(g)$
- 

(25) Consider the following reaction at equilibrium:



This reaction will shift to the right with \_\_\_\_\_

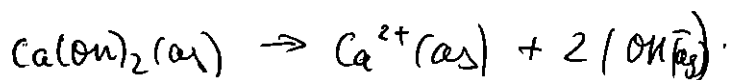
- a) increasing both temperature and pressure
  - b) increasing temperature and decreasing pressure
  - c) decreasing both temperature and pressure
  - d) decreasing temperature and increasing pressure
  - e) the addition of extra  $N_2$  to the container
- 

(26) What is the conjugate base of  $OH^-$ ?

- a)  $O_2$
  - b)  $O^-$
  - c)  $H_2O$
  - d)  $O^{2-}$
  - e)  $OH^+$
- 

(27) What is the pH of a 0.053 M solution of  $Ca(OH)_2$

- a) 1.30
- b) 12.7
- c) 0.97
- d) 13.0
- e) -0.97

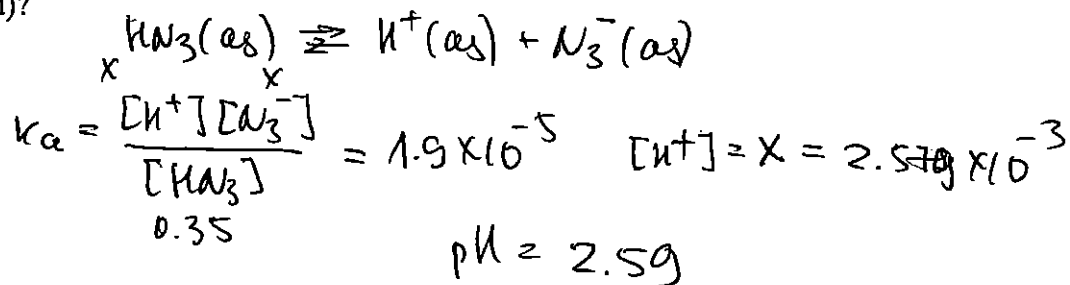


$$[OH^-] = 0.106 \text{ M}$$

$$pOH = 0.97, \quad pH = 14.00 - 0.97 = 13.03$$

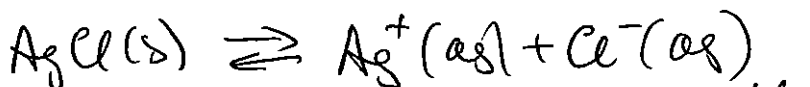
(28) The  $K_a$  of  $\text{HN}_3$  is  $1.9 \times 10^{-5}$  at  $25^\circ\text{C}$ . What is the pH of a  $0.35 \text{ M}$  solution of  $\text{HN}_3$  ( $\text{HN}_3$  is hydrozoic acid)?

- a) 11.41
- b) 2.37
- c) 5.18
- d) 2.59
- e) -2.37



(29) In which of the following aqueous solutions would you expect  $\text{AgCl}$  to have the highest solubility?

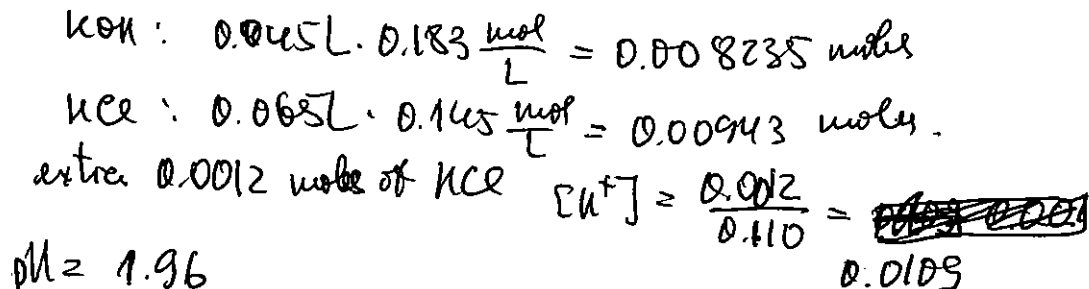
- a) pure water
- b)  $0.020 \text{ M BaCl}_2$
- c)  $0.015 \text{ M NaCl}$
- d)  $0.020 \text{ M AgNO}_3$
- e)  $0.20 \text{ M KCl}$



} will shift equilibrium to the left.

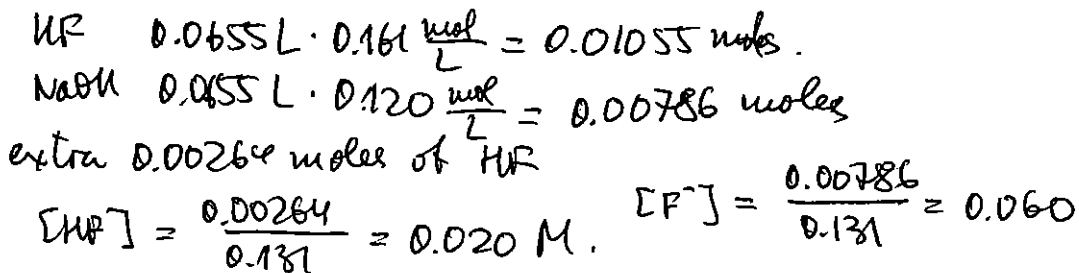
(30) The pH of a solution prepared by mixing  $45 \text{ mL}$  of  $0.183 \text{ M KOH}$  with  $65 \text{ mL}$  of  $0.145 \text{ M HCl}$  is \_\_\_\_\_

- a) 1.31
- b) 2.92
- c) 0.74
- d) 1.97
- e) 70.145



(31)  $65.50 \text{ mL}$  of  $0.161 \text{ M HF}$  is titrated with  $0.120 \text{ M NaOH}$ . What is the pH after  $65.50 \text{ mL}$  of base have been added ( $K_a$  for  $\text{HF}$  is  $6.8 \times 10^{-4}$ )

- a) 12.778
- b) 7.000
- c) 3.634
- d) 8.119
- e) 4.631



$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]} = 3.167 + 0.477 = 3.644$$

(32) Given the following table of  $K_{sp}$  values, determine which compound listed has the smallest solubility.

Compound

$K_{sp}$

$CdCO_3$

$5.2 \times 10^{-12}$

$$[Cd^{2+}] : \sqrt{5.2 \times 10^{-12}} = 2.28 \times 10^{-6}$$

$Cd(OH)_2$

$2.5 \times 10^{-14}$

$$[Cd^{2+}] : \sqrt[3]{\frac{2.5 \times 10^{-14}}{4}} = 2.92 \times 10^{-5}$$

$AgI$

$8.3 \times 10^{-17}$

$$[Ag^+] : \sqrt{8.3 \times 10^{-17}} = 9.1 \times 10^{-9}$$

$Fe(OH)_3$

$4 \times 10^{-38}$

$$[Fe^{3+}] : \sqrt[4]{\frac{4 \times 10^{-38}}{27}} = 1.96 \times 10^{-10}$$

$ZnCO_3$

$1.4 \times 10^{-11}$

$$[Zn^{2+}] = \sqrt{1.4 \times 10^{-11}} = 3.74 \times 10^{-6}$$

a)  $CdCO_3$

b)  $Cd(OH)_2$

c)  $AgI$

d)  $Fe(OH)_3$

e)  $ZnCO_3$

(33) Select the substance that is thought to be partially responsible for depleting the concentration of ozone in the stratosphere.

a)  $CFCl_3$

b)  $CO_2$

c)  $O_2$

d)  $N_2$

e) He

(34) With thermodynamics, one cannot determine \_\_\_\_\_.

a) the speed of a reaction

b) the direction of a reaction

c) the extent of a reaction

d) in which direction a reaction is spontaneous

e) the temperature at which a reaction will be spontaneous

(35) The thermodynamic quantity that expresses the degree of disorder in a system is \_\_\_\_\_.

a) enthalpy

b) internal energy

c) bond energy

d) entropy

e) heat flow

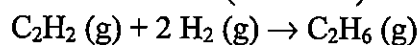
(36) Which species below has  $\Delta G_f^\circ = 0$ ?

- a)  Co (s)
- b) PF<sub>3</sub> (g)
- c) H<sub>2</sub>O (g)
- d) HCo(PF<sub>3</sub>)<sub>4</sub> (g)
- e) H<sub>2</sub>O (l)

(37) Consider the following table of thermodynamic data. All values are tabulated for 25°C.

Substance	$\Delta G_f^\circ$ (kJ/mol)	$S^\circ$ (J/mol·K)
C <sub>2</sub> H <sub>2</sub> (g)	209	201
C <sub>2</sub> H <sub>6</sub> (g)	-33	230
H <sub>2</sub> (g)	0	131

What is the value of  $\Delta H^\circ$  (in kJ/mol) for the reaction described below?



- a) -173
- b) 236
- c)  311
- d) -248
- e) 149

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ; \Delta H^\circ = \Delta G^\circ + T\Delta S^\circ$$

$$\Delta G^\circ = -262 \text{ kJ/mol}$$

$$\Delta S^\circ = -233 \text{ J/mol}\cdot\text{K}$$

$$T = 298 \text{ K}; \Delta H^\circ = -311 \text{ kJ/mol}$$

(38) Consider the following reaction



This reaction will always be spontaneous if  $\Delta H$  is \_\_\_\_ and  $\Delta S$  is \_\_\_\_.

- a) +, +
- b) -, -
- c)  +, +
- d) +, -
- e) +, 0

$$\Delta G = \Delta H - T\Delta S$$

$\Delta G$  should be negative.

(39) Which one of the following statements is true about the equilibrium constant for a reaction if  $\Delta G^\circ$  for the reaction is zero?

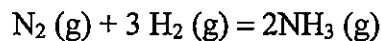
- a)  $K=0$
- b)   $K=1$
- c)  $K>1$
- d)  $K<1$
- e) more information is needed

$$\Delta G^\circ = -RT \ln K \text{ then}$$

$$\text{if } \Delta G^\circ = 0 \text{ then } \ln K = 0$$

$$K = 1$$

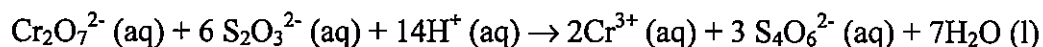
(40) The value of  $\Delta G^\circ$  for the reaction below is \_\_\_\_\_ kJ, given that  $K=5.0 \times 10^8$  and  $T=25^\circ\text{C}$ .



- a) 22
- b) -4.2
- c) -25
- d) -50**
- e) -22

$$\Delta G = -RT \ln K = -50 \text{ kJ}$$

(41) \_\_\_\_\_ is reduced in the reaction below.

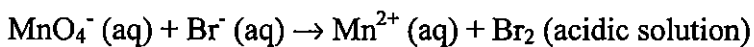


- a)  $\text{Cr}_2\text{O}_7^{2-}$**
- b)  $\text{S}_2\text{O}_3^{2-}$
- c)  $\text{H}^+$
- d)  $\text{Cr}^{3+}$
- e)  $\text{S}_4\text{O}_6^{2-}$

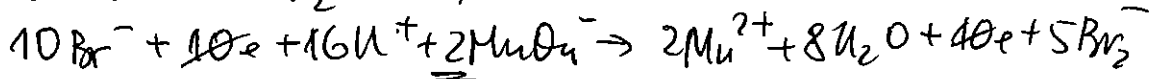
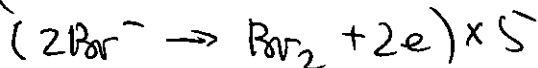
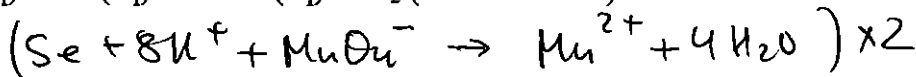
(42) Which of the following reactions is a redox reaction?

- a)  $\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}$
- b)  $\text{Pb}^{2+} + 2\text{Cl}^- \rightarrow \text{PbCl}_2$
- c)  $\text{AgNO}_3 + \text{HCl} \rightarrow \text{HNO}_3 + \text{AgCl}$
- d)  $\text{K}_2\text{CrO}_4 + \text{BaCl}_2 \rightarrow \text{BaCrO}_4 + 2\text{KCl}$
- e) None of these is a redox reaction**

(43) What is the coefficient of the permanganate ion when the following equation is correctly balanced?



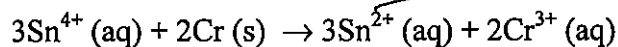
- a) 1
- b) 2**
- c) 3
- d) 5
- e) 4



(44) Given the following information

Half-reaction	$E^{\circ}_{\text{red}}$
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Sn}^{2+}(\text{aq})$	+0.15 V
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Cr}(\text{s})$	-0.74 V

determine the standard potential (in V) of a cell based on the reaction:



- a) +1.94
- b) +0.89
- c) +2.53
- d) -0.59
- e) -0.89

$$E^{\circ}_{\text{red}} = E^{\circ}_{\text{red}}(\text{cathode}) - E^{\circ}_{\text{red}}(\text{anode})$$
$$\cancel{+0.15\text{V}} = +0.15\text{V} - (-0.74\text{V}) = +0.89\text{V}$$

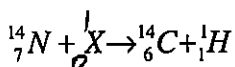
(45) A nonspontaneous electrochemical reaction has

- a)  $\Delta G=0$ ,  $E=0$ ,  $K>Q$
- b)  $\Delta G<0$ ,  $E>0$ ,  $K>Q$
- c)  $\Delta G>0$ ,  $E<0$ ,  $K<Q$
- d)  $\Delta G>0$ ,  $E<0$ ,  $K>Q$
- e)  $\Delta G<0$ ,  $E=0$ ,  $K>Q$

(46) What is the atomic number of an alpha particle?

- a) 0
- b) 1
- c) 2
- d) 4
- e) 18

(47) The reaction shown below is responsible for creating  $^{14}\text{C}$  in the atmosphere. What is the bombarding particle?



- a) alpha particle
- b) electron
- c) neutron
- d) positron
- e) proton

(48) The half-life for beta decay of strontium-90 is 28.8 years. A milk sample is found to contain 10.3 ppm strontium-90. How many years would pass before the strontium-90 concentration would drop to 1.0 ppm.

- a) 92.3
- b) 0.112
- c) 186
- d) 96.9
- e) 131

$$\ln \frac{N_t}{N_0} = -kt, \quad t = -\frac{1}{k} \ln \frac{N_t}{N_0} = 96.9 \text{ years}$$

$$N_t = 1.0 \text{ ppm}$$
$$N_0 = 10.3 \text{ ppm}$$

$$k = \frac{0.693}{t_{1/2}}$$

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(49) The most stable allotrope of oxygen is \_\_\_\_\_.

- a) H<sub>2</sub>O
  - b) O<sub>3</sub>
  - c) O<sub>2</sub>
  - d) HClO
  - e) O
- 

(50) P<sub>4</sub>O<sub>6</sub> is the anhydride of

- a) H<sub>3</sub>PO<sub>3</sub>
- b) H<sub>3</sub>PO<sub>4</sub>
- c) P<sub>4</sub>O<sub>10</sub>
- d) white phosphorus
- e) red phosphorus.

