START 8:10
END 10:00

CHM 102
Exam III

1. In aqueous solution, dithionite reacts with bismuth (III) to produce sulfite and bismuth metal:

$$S_2O_4^{2-}(aq) + Bi^{3+}(aq) \rightarrow SO_3^{2-}(aq) + Bi(s)$$

a) Assign oxidation states to all atoms in this reaction.

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$S_2O_4^{2-}$ + Bi^{3+} → SO_3^{2-} + Bi:
+3 −2 +3 +4 −2 0

b) Which reagent reacts as an oxidizing agent? Which reagent reacts as a reducing agent?

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Bi^{3+}: OXIDIZING AGENT, $S_2O_4^{2-}$: REDUCING AGENT

c) Using the method of half-reactions, balance this chemical equation.

$3\times(2H_2O + S_2O_4^{2-} \rightarrow 2SO_3^{2-} + 4H^+ + 2e^-)$

$2\times(3e^- + Bi^{3+} \rightarrow Bi:)$

$6H_2O + 3S_2O_4^{2-} + 6e^- + 2Bi^{3+} \rightarrow 6SO_3^{2-} + 12H^+ + 6e^- + 2Bi:$

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$6H_2O + 3S_2O_4^{2-} + 2Bi^{3+} \rightarrow 6SO_3^{2-} + 12H^+ + 2Bi:$

d) What volume of 0.10 M $S_2O_4^{2-}(aq)$ is required to make 50.0 g of Bi(*s*)?

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$$50.0\,g\ Bi: \cdot \frac{1\,mol\ Bi:}{208.98\,g\ Bi:} \cdot \frac{3\,mol\ S_2O_4^{2-}}{2\,mol\ Bi:} \cdot \frac{1\,L\ S_2O_4^{2-}}{0.10\,mol\ S_2O_4^{2-}} = \boxed{3.59\,L\ S_2O_4^{2-}}$$

2. Nobelium-259 was first discovered in 1965, and is most conveniently synthesized by the nuclear fusion of neon-22 nuclei with uranium-238.

a) Write a balanced nuclear equation for the formation of ^{259}No. What other particle is produced?

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$$^{22}_{10}Ne + {}^{238}_{92}U \longrightarrow {}^{259}_{102}No + {}^{1}_{0}n$$

↑ A NEUTRON IS PRODUCED

b) Nobelium-259 decays to fermium-255 with a half-life of 58 minutes. Write a balanced nuclear equation for this process. What form of radioactive decay is this?

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$$^{259}_{102}No \longrightarrow {}^{255}_{100}Fm + {}^{4}_{2}He$$

↑ α DECAY

c) How long does it take for a 99% of a sample of 1.0×10^{-6} g of ^{259}No to decay?

IF 99% DECAYS THEN 1% IS LEFT.

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$$\frac{N}{N_0} = \frac{1}{100}$$

$$\ln\left(\frac{N}{N_0}\right) = -(\ln 2)\frac{t}{t_{1/2}}$$

$$\ln\left(\frac{1}{100}\right) = -(\ln 2)\frac{t}{58}$$

$$t = \frac{58 \ln\left(\frac{1}{100}\right)}{-\ln 2} = \boxed{385 \text{ minutes}}$$

3. One of the steps in the industrial synthesis of nitric acid is the reaction of ammonia with oxygen to form nitric oxide and water:

$$NH_3(g) + O_2(g) \rightarrow NO(g) + H_2O(g)$$

a) Assign oxidation states to all atoms in this reaction.

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$$\underset{-3\ +1}{NH_3} + \underset{0}{O_2} \rightarrow \underset{+2\ -2}{NO} + \underset{+1\ -2}{H_2O}$$

b) Which atom is getting oxidized? Which atom is getting reduced?

1 N: oxidized, O: reduced

c) Using the method of half-reactions, balance this chemical equation.

$4\times(H_2O + NH_3 \rightarrow NO + 5H^+ + 5e^-)$

$5\times(4e^- + 4H^+ + O_2 \rightarrow 2H_2O)$

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$\cancel{4H_2O} + 4NH_3 + \cancel{20e^-} + \cancel{20H^+} + 5O_2 \rightarrow 4NO + \cancel{20H^+} + \cancel{20e^-} + \cancel{10H_2O}$

5 $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

d) A standard DOT 105J series rail car full of ammonia contains 33,500 gallons (1.27×10^5 L). How many moles of oxygen are required to completely react with this quantity of ammonia? The density of liquid ammonia is 0.6818 g / mL.

5 $1.27\times10^5\ L\ NH_3 \cdot \frac{1000\ mL}{1\ L} \cdot \frac{0.6818\ g\ NH_3}{1\ mL\ NH_3} \cdot \frac{1\ mol\ NH_3}{17.03\ g\ NH_3} \cdot \frac{5\ mol\ O_2}{4\ mol\ NH_3}$

$= 6.36\times10^6 \sim 10$

4. Explain the following phenomena:

a) Permanganate (MnO_4^-) is a common strong oxidizing agent, but manganese in permanganate is never oxidized.

WHEN MnO_4^- REACTS AS AN OXIDIZER, IT CAUSES OTHER REACTANTS TO BECOME OXIDIZED, WHILE IT GETS REDUCED.

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b) A source of gamma radiation is more dangerous than a source of alpha radiation, despite the fact that an alpha particle can cause more molecular damage than a gamma ray.

TINY GAMMA RAYS CAN PENETRATE MUCH FARTHER INTO MATTER THAN MASSIVE α-PARTICLES.

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c) The molar mass of a natural sample of bromine is about 80 g / mol, but bromine has no naturally occurring isotope of mass number 80.

THE MOLAR MASS IS A WEIGHTED AVERAGE OF ALL NATURALLY OCCURRING ISOTOPES. IN THIS CASE BROMINE IS NATURALLY ABOUT HALF ^{79}Br AND HALF ^{81}Br.

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5. For this problem, refer to the activity series at the right:

The Activity Series

$Li(s) \rightarrow Li^+(aq) + e^-$
$K(s) \rightarrow K^+(aq) + e^-$
$Ca(s) \rightarrow Ca^{2+}(aq) + 2\ e^-$
$Na(s) \rightarrow Na^+(aq) + e^-$
$Mg(s) \rightarrow Mg^{2+}(aq) + 2\ e^-$
$Al(s) \rightarrow Al^{3+}(aq) + 3\ e^-$
$Mn(s) \rightarrow Mn^{2+}(aq) + 2\ e^-$
$Zn(s) \rightarrow Zn^{2+}(aq) + 2\ e^-$
$Cr(s) \rightarrow Cr^{3+}(aq) + 3\ e^-$
$Fe(s) \rightarrow Fe^{2+}(aq) + 2\ e^-$
$Ni(s) \rightarrow Ni^{2+}(aq) + 2\ e^-$
$Sn(s) \rightarrow Sn^{2+}(aq) + 2\ e^-$
$Pb(s) \rightarrow Pb^{2+}(aq) + 2\ e^-$
$\mathbf{H_2(g) \rightarrow 2\ H^+(aq) + 2\ e^-}$
$Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^-$
$Ag(s) \rightarrow Ag^+(aq) + e^-$
$Au(s) \rightarrow Au^{3+}(aq) + 3\ e^-$

a) Are the following reactions spontaneous?

i) $Sn + Cu^{2+} \rightarrow Sn^{2+} + Cu$ YES

3 ii) $Li^+ + Ag \rightarrow Li + Ag^+$ NO

iii) $Ni^{2+} + Fe \rightarrow Ni + Fe^{2+}$ YES

b) Suppose you were choosing materials for a chemical plant. Would you pick copper or steel pipe for a process that runs under acidic conditions? Explain.

COPPER. COPPER IS LOWER IN THE ACTIVITY SERIES THAN HYDROGEN SO IT DOES NOT

4 REACT WITH ACID WHEREAS IRON DOES.

c) Write a balanced chemical equation for the dissolution of zinc in acid.

$Zn \rightarrow Zn^{2+} + 2e^-$

$2e^- + 2H^+ \rightarrow H_2$

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$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$

d) How many moles of HCl are required to dissolve 100.0 g of Zn?

4 $100.0\text{ g } Zn \cdot \frac{1\text{ mol } Zn}{65.41\text{ g } Zn} \cdot \frac{2\text{ mol } H^+}{1\text{ mol } Zn} = \boxed{3.06\text{ mol HCl}}$

For the remaining questions, choose the letter that corresponds to the best answer.

6. Which of the following are oxidation-reduction reactions?

I. $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$
II. $Cu(s) + 2\ AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2\ Ag(s)$
III. $CO_2(g) + 2\ LiOH(s) \rightarrow Li_2CO_3(s) + H_2O(l)$
IV. $2\ HCl(aq) + 2\ Na_2CrO_4(aq) \rightarrow Na_2Cr_2O_7(aq) + 2\ NaCl(aq) + H_2O(l)$
V. $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$

(A) **I** and **II**
(B) **III** and **IV**
(C) **I, II,** and **V**
(D) **I, III,** and **IV**
(E) **I, IV,** and **V**

7. How many neutrons, protons, and electrons are in an atom of platinum-195?

(A) 78 neutrons, 78 protons, 195 electrons
(B) 78 neutrons, 78 protons, 117 electrons
(C) 117 neutrons, 78 protons, 195 electrons
(D) 117 neutrons, 78 protons, 78 electrons
(E) 195 neutrons, 78 protons, 78 electrons

$^{195}_{78}Pt$

8. Astatine-217 is unstable and undergoes the following series of decays: α, β, α, β. What nucleus is formed at the end of this decay series?

(A) $^{209}_{79}Au$
(B) $^{207}_{81}Tl$
(C) $^{209}_{81}Tl$
(D) $^{207}_{82}Pb$
(E) $^{209}_{83}Bi$

$^{217}_{85}At \rightarrow {}^{4}_{2}He + {}^{213}_{83}Bi \rightarrow {}^{0}_{-1}e + {}^{213}_{84}Po$

$^{209}_{83}Bi + {}^{0}_{-1}e \leftarrow {}^{209}_{82}Pb + {}^{4}_{2}He$

9. Tritium has a half-life of 12.3 years. How long does it take for a 48 g sample of tritium to decay to 6.0 g?

(A) 12 years
(B) 21 years
(C) 25 years
(D) 37 years
(E) 49 years

$48 \rightarrow 24 \rightarrow 12 \rightarrow 6$
$t_{1/2}\quad t_{1/2}\quad t_{1/2}$

$3t_{1/2} = 12.3 \times 3 = 36.9$

10. The following observations are made in the laboratory:

$Cd(s) + Ni^{2+}(aq) \rightarrow Cd^{2+}(aq) + Ni(s)$ spontaneous
$Cd(s) + Fe^{2+}(aq) \rightarrow Cd^{2+}(aq) + Fe(s)$ not spontaneous
$Fe(s) + Ni^{2+}(aq) \rightarrow Fe^{2+}(aq) + Ni(s)$ spontaneous

Which of the following is true about the relative reactivities of cadmium, nickel, and iron metal?

(A) $Cd(s) > Ni(s) > Fe(s)$
(B) $Ni(s) > Fe(s) > Cd(s)$
(C) $Ni(s) > Cd(s) > Fe(s)$
5 (D) $Fe(s) > Cd(s) > Ni(s)$
(E) $Fe(s) > Ni(s) > Cd(s)$

11. Strontium-90 is an unstable nuclide produced in nuclear fallout that is dangerous because it can replace calcium in the bones. It is consumed by the following process:

$$^{90}_{38}Sr \rightarrow {}^{0}_{-1}e + {}^{90}_{39}Y$$

What is this process an example of?

(A) fission
(B) positron emission
(C) α decay
5 (D) β decay
(E) γ decay

12. Which of the following statements are *false* about oxidation-reduction reactions?

I. ✓ Oxidation is a loss of electrons.
II. ✗ An oxidizing agent loses electrons.
III. ✗ The oxidation state of an oxidizing agent will increase.
IV. ✗ A reducing agent gets reduced.
V. ✓ An atom undergoing reduction will have a decrease in oxidation state.

(A) **I** and **V**
(B) 3 **II** and **IV**
(C) **I**, **III**, and **V**
5 (D) **II**, **III**, and **IV**
(E) **I**, **IV**, and **V**

13. The nuclide $^{232}_{90}\text{Th}$ is radioactive. When one of these atoms decays, a series of α and β emissions occur, taking the atom through many transformation to end up as an atom of $^{208}_{82}\text{Pb}$. How many α particles are emitted in converting $^{232}_{90}\text{Th}$ to $^{208}_{82}\text{Pb}$?

(A) 6
(B) 8
(C) 2
(D) 214
(E) 4

232 → 208 24 mass unit
= 6 4/2 He

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14. In the following reaction, what is oxidized and what is reduced?

$$3\ CoSO_4(aq) + 5\ KI(aq) + KIO_3(aq) + 3\ H_2O(l) \rightarrow 3\ Co(OH)_2(s) + 3\ K_2SO_4(aq) + 3\ I_2(aq)$$

+2 +6 -2 +1 -1 +1 +5 -2 +1 -2 +2 -2 +1 +1 +6 -2 0

(A) Co^{2+} is oxidized and the I in IO_3^- is reduced.
(B) I^- is oxidized and the I in IO_3^- is reduced.
(C) I in IO_3^- is oxidized and H_2O is reduced.
(D) I^- is oxidized and Co^{2+} is reduced.
(E) None of these are correct.

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15. An artifact contains 12.5% of the amount of ^{14}C present in living things. The half-life of ^{14}C is 5,730 years. How old is the artifact?

(A) 1,910 years
(B) 2,865 years
(C) 11,460 years
(D) 17,190 years
(E) 22,920 years

100% → 50% → 25% → 12.5%
$t_{1/2}$ $t_{1/2}$ $t_{1/2}$
3 $t_{1/2}$ = 3 (5730) = 17190

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Equations for radioactive decay

$$N = N_0\, e^{-(\ln 2)\frac{t}{t_{1/2}}}$$

$$\ln\left(\frac{N}{N_0}\right) = -(\ln 2)\frac{t}{t_{1/2}}$$