

AP Chemistry – Electrochemistry, Nuclear Chemistry, Comprehensive Exam

79 possible

Name: Key Date: _____ Period: _____

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1. A standard electrochemical cell is made by dipping a silver electrode into a 1.0M Ag⁺ solution and a cadmium electrode into a 1.0M Cd²⁺ solution.

a. What is the spontaneous chemical reaction, and what is the maximum potential produced by the cell?

$$E_{Ag^+ \rightarrow Ag}^{\circ} = 0.80V \quad E_{Cd^{2+} \rightarrow Cd}^{\circ} = -0.40V$$

$$E_{cell}^{\circ} = 0.80 - (-0.40) = 1.20V$$

(3) x 2

Reaction: $2Ag^+(aq) + Cd(s) \rightarrow 2Ag(s) + Cd^{2+}$ Cell Potential: 1.20 V

b. What would be the effect on the potential of this cell if sodium sulfide were added to the Cd²⁺ half-cell and CdS were precipitated? Explain.

Given $E_{cell} = E_{cell}^{\circ} - \frac{0.0592}{n} \log Q$

$Q = \frac{[Cd^{2+}]}{[Ag^+]}$ precipitating Cd²⁺ out would make the numerator of Q smaller therefore Q < 1 and log Q is negative & E_{cell} increases

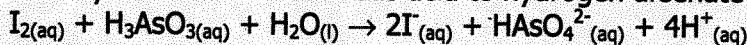
x 2

c. What would be the effect on the potential of the cell if the size of the silver electrode were doubled?

The solid silver electrode is not part of Q, therefore [there is no effect]

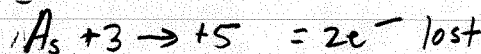
x 2

2. In an analytical determination of arsenic, a solution containing arsenious acid, H₃AsO₃, potassium iodide, and a small amount of starch is electrolyzed. The electrolysis produces free iodine from iodide ion, and the iodine immediately oxidizes the arsenious acid to hydrogen arsenate ion, HAsO₄²⁻.



When the oxidation of arsenic is complete, the free iodine combines with the starch to give a deep blue color. If, during a particular run, it takes 65.4s for a current of 10.5mA to give an endpoint (indicated by the blue color), how many grams of arsenic are present in the solution?

$$10.5mA = .0105A \quad .0105C/s (65.4s) = .67725C$$



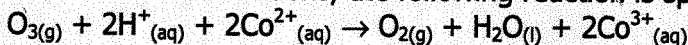
$$.67725C \left(\frac{1 \text{ mole } e^-}{96,480C} \right) \left(\frac{1 \text{ mol } As}{2 \text{ mole } e^-} \right) = 3.51 \times 10^{-6} \text{ mol}$$

$$3.51 \times 10^{-6} \text{ mol} (74.92 \text{ g/mol}) = 2.63 \times 10^{-4} \text{ g As}$$

3 x

Answer: 2.63×10^{-4} g As

3. Under standard conditions for all concentrations, the following reaction is spontaneous at 25.0°C.



If [H⁺] is decreased so that the pH = 9.10, what value will E_{cell} have, and will the reaction be spontaneous at this [H⁺]?

pH = 9.10

$$[H^+] = 10^{-pH} = 10^{-9.10} = 7.943 \times 10^{-10}$$

standard conditions implies 1atm of 1M concentration

$$E_{cell} = E_{cell}^{\circ} - \frac{0.0592}{n} \log Q$$

$$.25V - \frac{0.0592}{2} \log \left(\frac{1}{[7.943 \times 10^{-10}]^2} \right)$$

$$E_{cell} = \underline{\underline{-.29V}} \text{ V}$$

Spontaneous? Not Spontaneous

$$E_{CO_3^{3-} \rightarrow CO_3^{2-}}^{\circ} = 1.82V$$

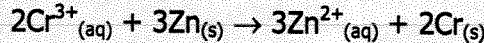
$$E_{O_3 \rightarrow H_2O}^{\circ} = 2.07V$$

$$E_{cell}^{\circ} = 2.07V - (1.82V) = .25V$$

x 2

$$E_{cell} = .25V - .5387 = \underline{\underline{-.29V}}$$

4. Consider the following cell reaction at 25.0°C



a. Calculate the standard cell potential of this cell from the standard electrode potentials

$$E_{\text{Zn}^{2+} \rightarrow \text{Zn}}^{\circ} = -0.76\text{V} \quad E_{\text{Cr}^{3+} \rightarrow \text{Cr}}^{\circ} = -0.74\text{V}$$

$$-0.74 + 0.76 = 0.02\text{V} = E_{\text{cell}}^{\circ}$$

x3
 $E_{\text{cell}}^{\circ} = 0.02\text{V}$

b. From the above cell potential, calculate ΔG° for the reaction.

$$\Delta G^{\circ} = -nFE^{\circ}$$

$$= -6(96,480 \frac{\text{J}}{\text{V}\cdot\text{mole}})(0.02\text{V})$$

$$= -11577.6\text{J}$$

$v = \frac{\text{J}}{\text{C}}$
 $C = \frac{\text{J}}{\text{V}}$

x3
 $\Delta G^{\circ} = -1.2 \times 10^4\text{kJ}$

c. Use the data from your textbook appendices to calculate ΔH° for the reaction. $\text{Cr}^{3+} = -143.5\text{kJ/mol}$

ΔH_f° elements (in std state) = 0

$\text{Zn}^{2+} = -153.9\text{kJ/mol}$

x3
 $\Delta H^{\circ} = -174.7\text{kJ}$

$$\Delta H^{\circ} = [3(-153.9)] - [2(-143.5\text{kJ/mol})]$$

$$= -174.7\text{kJ}$$

d. Use the values of ΔH° and ΔG° calculated above to determine ΔS° for the reaction.

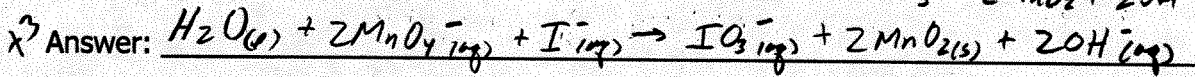
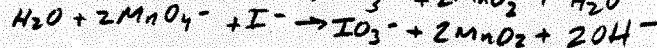
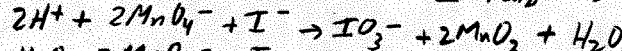
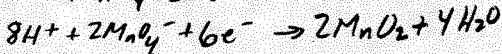
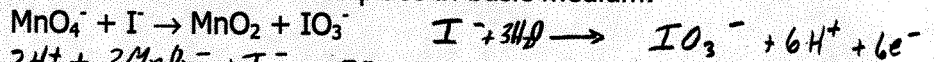
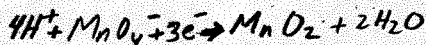
$$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

x3
 $\Delta S^{\circ} = -547\text{J/K}$

$$-11577.6\text{J} = -174,700\text{J} - 298.15(\Delta S^{\circ})$$

$$163122.4 = -298.15(\Delta S^{\circ}) \quad \Delta S^{\circ} = -547\text{J/K}$$

5. Balance the following oxidation-reduction reaction which takes place in basic medium.



6. Polonium-210 has a half-life of 138.4 days, decaying by alpha emission. Suppose the helium gas originating from the alpha particles in this decay were collected. What volume of helium at 25.0°C and 735 mmHg could be obtained from 1.0000g of polonium dioxide, PoO_2 , in a period of 48.0h?

$$\text{PoO}_2 = 241\text{g/mol} \quad 1.0000\text{g} / 241\text{g/mol} = 0.004149\text{ mol PoO}_2 = 0.004149\text{ mol Po}$$

$$PV = nRT$$

$$(0.967)(V) = (4.166 \times 10^{-5})(0.0821)(298.15\text{K})$$

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

$$k = 0.693/138.4 = 0.0050\text{ days}^{-1}$$

x3 Answer: 0.001L

$$\ln\left(\frac{N_0}{N_t}\right) = kt$$

$$\ln\left(\frac{0.004149}{x}\right) = (0.0050)(2.0\text{ days})$$

$$x = 0.004108\text{ mol left}$$

7. A sample of sodium phosphate, Na_3PO_4 , weighing 54.5mg contains radioactive phosphorus-32 (with mass of 32.0amu). If 15.6% of the phosphorus atoms in the compound is phosphorus-32 (the remainder is naturally occurring phosphorus, how many disintegrations of this nucleus occur per second in this sample? Phosphorus-32 has a half-life of 14.3d.

P = 30.97 g/mol Natural

x3
 $(0.0545\text{g} \times 0.03042) = 5.181 \times 10^{-5}\text{mol}$

$$\times 6.022 \times 10^{23} = 3.120 \times 10^{19}\text{ atoms}$$

③ Mass% = $\frac{4.992}{164.098} \times 100 = 0.03042$

$$k = \frac{0.693}{14.3 \times 24 \times 3600} = 5.609 \times 10^{-7}\text{s}^{-1}$$

Answer: 1.75×10^{13} disintegrations/second

② $3(22.99) + [(0.156)(32) + (0.844)(30.97)] + 4(15.9994)$

⑤ $kN = (3.120 \times 10^{19}\text{ atoms})(5.609 \times 10^{-7}\text{s}^{-1}) = 1.75 \times 10^{13}$ molar mass = 164.098

$$V = \frac{J}{C}$$

$$kg \frac{m^2}{s^2}$$

$$W = Fd = \frac{kg \cdot m^2}{s^2} \rightarrow \text{Joules}$$

8. a. Plutonium-239 has been used as a power source for heart pacemakers. What is the energy obtained from the following decay of 215mg of plutonium-239 (Pu-239 = 239.05216u; He-4 = 4.00260u; U-235 = 235.04392u)

(3) $(.215g) \times \frac{1 \text{ mol}}{239.05216g} = 8.994 \times 10^{-4} \text{ mol}$
 $(8.994 \times 10^{-4} \text{ mol}) \times (6.022 \times 10^{23} \text{ atoms/mol}) = 5.416 \times 10^{20} \text{ atoms}$
 $(9.362 \times 10^{-30} \text{ kg/atom}) \times (5.416 \times 10^{20} \text{ atoms}) = 5.071 \times 10^{-9} \text{ kg total}$
 ${}_{94}^{239}\text{Pu} \rightarrow {}_2^4\text{He} + {}_{92}^{235}\text{U} \rightarrow 235.04392 \text{ u}$
 $\Delta m = .00564 \text{ u/atom}$
 $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
 $.00564 \text{ u} (1.66 \times 10^{-27} \text{ kg/u}) = 9.362 \times 10^{-30} \text{ kg/atom}$
 (mass defect)
 $E = (5.071 \times 10^{-9} \text{ kg}) (3.00 \times 10^8 \text{ m/s})^2 = 4.5635 \times 10^8 \text{ J}$

x3

b. Suppose the electric energy produced from this amount of plutonium-239 is 25.0% of this value. What is the minimum grams of zinc that would be needed for the standard voltaic cell

Zn | Zn²⁺ || Cu²⁺ | Cu to obtain the same electric energy? $4.56 \times 10^8 \text{ J} (.250) = 1.14 \times 10^8 \text{ J}$

$1.10 \text{ V} \approx 1.10 \text{ J/C}$
 $1.14 \times 10^8 \text{ J} \left(\frac{1 \text{ C}}{1.10 \text{ J}} \right) \left(\frac{1 \text{ mole } e^-}{96,480 \text{ C}} \right) \left(\frac{1 \text{ mol Zn}}{2 \text{ mole } e^-} \right) \left(\frac{65.39 \text{ g Zn}}{1 \text{ mol Zn}} \right)$
 $E_{\text{Zn}^{2+} \rightarrow \text{Zn}}^0 = -0.76 \text{ V} \quad E_{\text{Cu}^{2+} \rightarrow \text{Cu}}^0 = +0.34 \text{ V}$

x3

Answer: $3.51 \times 10^4 \text{ g zinc} = 35,120.1 \text{ g}$
 $(35.1 \text{ kg}) \quad E_{\text{cell}}^0 = 0.34 - (-0.76) = 1.10 \text{ V}$

9. The half-life of calcium-47 is 4.536 days and it decays by the emission of a beta particle.

a. Write a balanced equation for the decay of Ca-47

x2

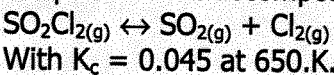


b. If 10.0μg of Ca-47 is needed for an experiment, what mass of ⁴⁷CaSO₄ must be ordered if it takes 48h for it to arrive from the supplier?

$\text{mass \%} = \frac{47}{143.063} = .3285$
 $\lambda = \frac{.693}{4.536} = .1528 \text{ day}^{-1}$
 $13.57 \mu\text{g} / .3285 = 41.3 \mu\text{g}$
 $\ln\left(\frac{N_0}{N_t}\right) = kt$
 $\ln\left(\frac{N_0}{10.0 \mu\text{g}}\right) = (.1528)(2.0) \quad \frac{N_0}{10.0 \mu\text{g}} = 1.3574$
 $N_0 = 13.57 \mu\text{g}$

x3

10. Sulfuryl chloride is used in organic chemistry as a chlorinating agent. At moderately high temperatures it decomposes as follows:



$8.25 \text{ g SO}_2\text{Cl}_2$
 134.9638 g/mol
 $\frac{8.25 \text{ g}}{134.9638 \text{ g/mol}} = .0611$

a. A sample of 8.25g of SO₂Cl₂ is placed in a 1.00L reaction vessel and heated to 650.K. What are the equilibrium concentrations of all the species?

$K_c = \frac{[\text{SO}_2][\text{Cl}_2]}{[\text{SO}_2\text{Cl}_2]}$
 $0.045 = \frac{(x)(x)}{(.0611 - x)}$
 $x = .0346$

(2+2+2)

[SO₂Cl₂] = 0.0265 M; [SO₂] = 0.0346 M; [Cl₂] = 0.0346 M

b. What percentage of SO₂Cl₂ has decomposed?

$\frac{.0346}{.0611} \times 100 =$

x3

Answer: 56.6 %

c. If 5.00g of chlorine is inserted into the reaction vessel, what qualitative effect would this have on the fraction of SO_2Cl_2 that has decomposed?

$\times 2$ Adding chlorine drives the reaction towards SO_2Cl_2 (Le Chatelier's principle)
This will decrease the amount of SO_2Cl_2 decomposed.

11. The following data were collected for the reaction $\text{A}(\text{g}) + \text{B}(\text{g}) \rightarrow \text{Products}$

Experiment	$[\text{A}_0](\text{M})$	$[\text{B}_0](\text{M})$	Rate (M/s)
1	0.0100	0.100	1.0×10^{-3}
2	0.0300	0.100	3.0×10^{-3}
3	0.0300	0.300	2.7×10^{-2}

$$\frac{3.0 \times 10^{-3}}{1.0 \times 10^{-3}} = \frac{k [0.0300]^x [0.100]^y}{k [0.0100]^x [0.100]^y}$$

$$3 = 3^x \quad x = 1$$

a. Determine the rate law for this reaction.

$$\frac{2.7 \times 10^{-2}}{3.0 \times 10^{-3}} = \frac{k [0.0300]^x [0.300]^y}{k [0.0300]^x [0.100]^y}$$

$$9 = 3^y \quad y = 2$$

$\times 3$ Answer: Rate = $k [\text{A}] [\text{B}]^2$

b. Calculate the rate constant.

$$2.7 \times 10^{-2} = k [0.0300] [0.300]^2$$

$\times 3$ Answer: $k = 10 \text{ M}^{-2} \text{ s}^{-1}$

c. Calculate the rate when $[\text{A}] = 0.200\text{M}$ and $[\text{B}] = 0.200\text{M}$

$\times 3$ Rate = $18.0 \times 10^{-2} \text{ M/s}$ Rate = $10 \text{ M}^{-2} \text{ s}^{-1} (0.200\text{M})(0.200)^2$

12. Tungsten has a body-centered cubic lattice with all atoms at the lattice points. The edge length of the unit cell is 316.5pm. The atomic mass of tungsten is 183.8u. Calculate the density of W.

$$2 \text{ atoms} (183.8 \text{ u/atom}) (1.66 \times 10^{-24} \text{ g/u}) = 6.102 \times 10^{-22} \text{ g}$$

$$d = m/V = 6.102 \times 10^{-22} \text{ g} / 3.17 \times 10^{-23} \text{ cm}^3 = 19.249$$



bcc = $\frac{1}{8}(8) + 1 = 2 \text{ atoms/cell}$
 $V_{\text{cell}} = (3.165 \times 10^{-8} \text{ cm})^3 = 3.17 \times 10^{-23} \text{ cm}^3$

$\times 3$ Answer: 19.25 g/cm³

13. The vapor pressure of benzene is 100.0mmHg at 26.1°C and 400.0mmHg at 60.6°C. What is the boiling point of benzene at 760.0mmHg?

From the Clausius - Clapeyron Equation

$$\ln\left(\frac{760.0}{100.0}\right) = \frac{33365.8}{8.314} \left(\frac{1}{299.25} - \frac{1}{T_2}\right)$$

$$T_2 = 352.57 \text{ K} \quad 352.57 - 273.15 = 79.4$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{\text{vap}}}{R} \left(\frac{1}{T_1} - \frac{1}{T_2}\right) \quad R = 8.314 \text{ J/mol K}$$

$$\ln\left(\frac{400}{100}\right) = \frac{\Delta H_{\text{vap}}}{8.314} \left(\frac{1}{299.25} - \frac{1}{333.75 \text{ K}}\right) \quad \Delta H_{\text{vap}} = 33365.8 \text{ J}$$

$\times 3$ Answer: 79 °C

14. A molecular compound is composed of 60.4% Xe, 22.1% O and 17.5% F, by mass. If the molecular weight is 223u

a. Draw a Lewis structure for the molecular compound Xe = 131.293 O = 15.9994 F = 18.998

$$\text{Xe} = \frac{223 \times 0.604}{131.293} = 1.03 \quad \text{O} = \frac{223 \times 0.221}{15.9994} = 3.08 \quad \text{F} = \frac{223 \times 0.175}{18.998} = 2.05$$

b. Predict the molecular geometry in terms of VSEPR and valence bond theory.

molecular geometry is trigonal bipyramidal w/ Sp^3d hybridization

