Chemistry 1B SU'12, Exam 2 Name KEY

Multiple Choice Section. Answer each of the following questions and list your answers on page 2 in the space provided. Each multiple-choice question is worth 3 points.

Consider the following electrochemical cell, which takes place in a fuel cell:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

1. Which compound is oxidized?

(A) H_2 (B) O_2 (C) H_2O (D) H^+ (E) OH^-

2. Which compound is reduced?

(A) H_2 (B) O_2 (C) H_2O (D) H^+ (E) OH^-

3. What is the standard potential, in Volts, for the overall reaction?

(A) 0 (B) -0.83 (C) -0.40 (D) 1.23 (E) 2.60

4. How many electrons are transferred in this reaction?

(A) 0 (B) 1 (C) 2 (D) 4 (E) 8

5. If a current of 5.34 Amps is produced over a 21 minute time period, what is the maximum electrical work that this battery can do? $w = -ItE_{cell} = -(5.34A)(21min \times 60s/min)(1.23V) = 8275.9 J$

(A) 8.3 kJ (B) 0.1 kJ (C) 0 kJ (D) 17.5 kJ (E) 5.6 kJ

The nuclide ^{65}Ni undergoes radioactive decay with a half-life of 2.52 hrs. The mass of a ^{65}Ni atom is 64.930 u.

6. What type of decay would this nuclide undergo?

(A) Alpha decay
(B) Gamma-ray Emission
(C) Electron Emission
(D) Internal Conversion
(E) Positron Emission

7. What would the daughter nucleus be in this case?

(A) $^{65}_{27}Co$ (B) $^{66}_{28}Ni$ (C) $^{65}_{29}Cu$ (D) $^{61}_{26}Fe$ (E) $^{61}_{30}Zn$

8. If the decay rate is measured at 402 s^{-1}. How many grams were in the original sample?

(A) 5.67×10^{-16} g (B) 1.45×10^{6} g (C) 1.08×10^{-22} g
(D) 1.46×10^{3} g (E) 3.42×10^{8} g

$k = \frac{\ln 2}{2.52 h} = 0.2751 h^{-1}$

$A = kN = 402 s^{-1} \cdot 60 s/min \times 60 min/hr = 1.45 \times 10^{6} h^{-1} = 0.2751 h^{-1} \cdot N$

$N = 5.261 \times 10^{6}$ atoms $\times$ 1 mol/6.022$\times 10^{23}$ $\times$ 64.93 g/mol $= 5.67 \times 10^{-16}$

Chemistry 1B SU'12, Exam 2 Name KEY

The $^{226}_{88}Ra$ nuclide (atomic mass = 226.025403 u) undergoes alpha decay with a half-life of 1600 years. The daughter nuclide ($^{222}_{86}Rn, t_{1/2} = 3.824\ days$) has an atomic mass of 222.0175777 u.

$\Delta m = 222.0175777\,u + 4.00260\,u$

9. What is the total energy released per disintegration?

$\Delta m = -226.025403\,u$

(A) 7.81×10^{-13} MeV (B) 5.20 MeV (C) 3.73×10^{3} MeV
(D) 4.87 MeV (E) 4.70×10^{14} MeV

$\Delta m = -0.0052253 \cdot 931.494\,MeV/u$

10. What is the maximum kinetic energy of the alpha particle?

(A) 4.38×10^{17} J (B) 75.2 J (C) 7.28×10^{-10} J
(D) 4.87 J (E) 7.79×10^{-13} J

$E = (.0052253\,u)(1.66054 \times 10^{-27}\,kg/u) \cdot (3 \times 10^{8})^2$

NOTE: Don't forget to go back and list your answers on page 2 in the space provided!!

Chemistry 1B SU'12, Exam 2 Name KEY

Calculations Section. Please show ALL work to receive partial credit. Place your final answers in a circle or box for clarity.

11. (**15 points**) A rock containing $^{238}_{92}U$ and $^{206}_{82}Pb$ was examined to determine its approximate age. The ratio of $^{206}_{82}Pb$ atoms to $^{238}_{92}U$ atoms was measured to be 0.115. Assume that no lead was originally present, and that all the $^{206}_{82}Pb$ formed through the years has remained in the rock. Calculate the age of the rock if the half-life of $^{238}_{92}U$ is 4.5×10^9 years.

$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{4.5\times10^9\ yrs} = 1.54\times10^{-10}\ yrs^{-1}$

$\ln(N/N_0) = -kt$ $\quad 0.115 = \frac{^{206}Pb\ current}{^{238}U\ current} = \frac{115}{1000}$ $\therefore 1115\ ^{238}U$ original

$\ln(1000/1115) = -(1.54\times10^{-10}\ yrs^{-1})\,t$

$\boxed{t = 7.1\times10^8\ yr}$

12. (**25 points**) Consider the reactions: $Fe^{3+} + 2e^- \rightarrow Fe(s)$ and $Cr^{2+} + 2e^- \rightarrow Cr(s)$.

(a) What are the E^0_{cell} for each of these reactions?

$Fe^{3+} + 3e^- \rightarrow Fe$ $\quad E^\circ_3 = ?$

$Fe^{3+} + e^- \rightarrow Fe^{2+}$ $\quad E^\circ_1 = 0.771V$

$Fe^{2+} + 2e^- \rightarrow Fe$ $\quad E^\circ_2 = -0.409V$

$\Delta G_3 = \Delta G_1 + \Delta G_2$

$-n_3 F E^\circ_3 = -n_1 F E^\circ_1 - n_2 F E^\circ_2$

$E^\circ_3 = \frac{-n_1 E^\circ_1 - n_2 E^\circ_2}{-n_3}$

$= \frac{(1)(0.771V) + (2)(-0.409V)}{(3)}$

$= \boxed{-0.0157V}$

$Cr^{2+} + 2e^- \rightarrow Cr$ $\quad E^\circ_3 = ?$

$Cr^{3+} + e^- \rightarrow Cr^{2+}$ $\quad E^\circ_1 = -0.424V$

$Cr^{3+} + 3e^- \rightarrow Cr$ $\quad E^\circ_2 = -0.74V$

$\Delta G_3 = -\Delta G_1 + \Delta G_2$

$-n_3 F E^\circ_3 = +n_1 F E^\circ_1 - n_2 F E^\circ_2$

$E^\circ_3 = \frac{n_1 E^\circ_1 - n_2 E^\circ_2}{-n_3}$

$= \frac{(1)(-0.424V) - (3)(-0.74V)}{-(2)}$

$= \boxed{-0.898V}$

(b) Are the disproportionations of Fe^{2+} and Cr^{2+} spontaneous? Explain your reasoning.

$2Fe^{2+} \rightarrow Fe^{3+} + Fe(s)$

$E^\circ = -0.409V - 0.771V$

$E^\circ = -1.18V$

$\Delta G = -nFE^\circ$

$E^\circ = \ominus \therefore \Delta G = \oplus$

NOT SPONTANEOUS

$2Cr^{2+} \rightarrow Cr^{3+} + Cr$

$E^\circ = -0.898V + 0.424V$

$E^\circ = -0.474V$

also NOT SPONTANEOUS

Chemistry 1B SU'12, Exam 2 Name KEY

13. (20 points) Calculate the binding energy of ${}^{9}_{3}Li$ in MeV (atomic mass ${}^{9}_{3}Li$ = 9.026789 u).

$$3\,{}^{1}_{1}H + 6\,{}^{1}_{0}n \rightarrow {}^{9}_{3}Li$$

$$\Delta m = (\text{mass } {}^{9}_{3}Li \text{ nucleus}) - (3 \times \text{mass } {}^{1}_{1}H \text{ nucleus} + 6 \times \text{mass neutron})$$

$$= (9.026789u - 3m_e) - (3(1.0078u - m_e) + 6(1.0087))$$

$$= 9.026789u - 3 \times 1.0078u - 6 \times 1.0087u$$

$$= -0.048811u \times 1.66 \times 10^{-27}\ \text{kg/amu} \rightarrow -8.10 \times 10^{-29}\ \text{kg/nucleus}$$

$$\Delta E = mc^2 = (-8.10 \times 10^{-29}\ \text{kg})(3 \times 10^{8}\ \text{m/s})^2 = -7.29 \times 10^{-12}\ \text{J/nucleus}$$

$$BE = -\Delta E / \#\text{nucleons} = 7.29 \times 10^{-12}\ \text{J} / 9\ \text{nucleons} = 8.10 \times 10^{-13}\ \text{J} \xrightarrow{\div 1.60 \times 10^{-13}\ \text{J/MeV}} \boxed{5.06\ \text{MeV}}$$

14. (20 points) Consider the two half reactions:

$$(Au^{3+} + 3e^- \rightarrow Au(s)) \times 2$$
$$(Hg_2^{2+} + 2e^- \rightarrow 2Hg(l)) \times 3$$

(a) Which is the cathode and which is the anode if this is set-up to be an electrolytic cell?

$Hg_2^{2+} + 2e^- \rightarrow 2Hg(l)$ – cathode $E° = 0.7961$ V

$Au^{3+} + 3e^- \rightarrow Au(s)$ – anode $E° = 1.42$ V

$E°_{cell} = 0.7961 - 1.42 = -.624$ V

(b) If E_{cell} is measured to be -0.573 V for this electrolytic cell at T=298 K. If the concentration of Hg_2^{2+} is 0.015 M, what is $[Au^{3+}]$ in moles/liter?

$$E = E°_{cell} - \frac{RT}{nF} \ln Q$$

$$-0.573V = -0.624V - \frac{(8.314\ \text{J/K·mol})(298\ \text{K})}{(6)(96485\ \text{C/mol})} \ln \frac{[Au^{3+}]^2}{[Hg_2^{2+}]^3}$$

$$-0.573V = -0.624V - 0.0042797 \ln \frac{[Au^{3+}]^2}{(.015)^3}$$

$$-11.92 = \ln [Au^{3+}]^2/(.015)^3$$

$$6.656 \times 10^{-6} = [Au^{3+}]^2/(.015)^3 \qquad \boxed{[Au^{3+}] = 4.75 \times 10^{-6}\ M}$$

(c) How many hours does it take to electro-deposit 3 grams of Au using 0.100 Amps?

$$3g\ Au \times \frac{1\ \text{mol Au}}{196.9666g} \times \frac{3\ \text{mol } e^-}{1\ \text{mol Au}} = 0.04569\ \text{mol } e^-$$

$$.04569\ \text{mol } e^- \times \frac{96485.34C}{\text{mol}} = 4408.7\ C$$

$$1C = 1A \cdot 1s \Rightarrow 4408.7C = 0.100A \cdot t$$

$$t = 44087\ \text{sec} = \boxed{12.2\ \text{hrs}}$$

15. (4 points each) True/False. Confirm whether each statement below is true or false. Explain your reasoning for each question in full sentences for full credit. Diagrams and/or figures are also valid and sometimes very useful for full explanations, but not required.

(a) All electrochemical cells require a salt bridge.

True. To move ions.

(b) All radioactive decay processes have first order kinetics.

True. $\ln(N/N_0) = -kt$ & $t_{1/2} = \ln 2/k$

(c) Typical exposure to radiation in our every lives is greatly increased by man-made radiation sources (i.e.- medical procedures, nuclear power plants, etc.)

False. ~126 mrem/yr Natural Sources
~67 mrem/yr Human Activities

(d) The nuclear reaction used most in nuclear power plants, a type of branching chain reaction, is called fusion.

False. Nuclear power plants use fission rxns (large nuclides breaking into small nuclides). Fusion takes light nuclides + combines to make heavier ones.

(e) Radiocarbon dating requires a correction factor due to the differences in CO_2 levels in the air between today and when the artifacts we are trying to date were made.

True

Chemistry 1B SU'12, Exam 2 Name KEY

16. (4 points each) **Short Answer. Use complete sentences in your explanations for full credit.**

(a) If an electrochemical cell reaction occurs spontaneously then would work be done on the system or by the system. Explain your answer, and give one example such a cell.

Work done by system.

$w_{elec} = \Delta G$ @ constant P,T

Example; batteries, galvanic electrochem. cell, etc.

(b) In an electrolytic cell which direction do the electrons flow (from the cathode to the anode or from the anode to the cathode)?

Electrons ALWAYS flow from anode to cathode

(c) Complete the missing information in the following nuclear reactions and list the type of decay that is occuring.

i.) ${}^{195}_{79}Au + ? \rightarrow {}^{195}_{78}Pt + v$ ${}^{0}_{-1}e$, Electron capture

ii) ${}^{237}_{93}Np \rightarrow {}^{4}_{2}He + ?$ ${}^{233}_{91}Pa$, α decay

iii) ${}^{38}_{19}K \rightarrow {}^{38}_{18}Ar + ?$ ${}^{0}_{1}e + \tilde{v}$, positron emission

iv) ${}^{0}_{+1}e + {}^{0}_{-1}e \rightarrow ?$ 2γ , Annihilation

(d) Is the change in mass for a radioactive decay reaction ever a positive value?

No, if it was then ΔE would be ⊕, making rxn not spontaneous

(e) What are you actually doing, in terms of electrochemical reactions, when recharging a rechargeable battery?

Running galvanic cell backwards by applying a voltage greater than E_{cell} + regenerating the reactants.

Creating electrolytic cell.