Chemistry 1A, Spring 2008

Final Exam, Version A

May 17, 2008

(180 min, closed book)

Name:____KEY______

SID:_________________________

TA Name:_____________________

1) Write your name on every page of this exam.

2) This exam has 25 multiple-choice questions and 5 short answer questions. Fill in the Scantron form AND circle your answer on the exam.

3) There is no penalty for guessing, so answer every question.

4) Some questions require selecting multiple answers for credit. These questions clearly state "Mark all that apply".

5) Show all work to receive credit on short answer questions.

Question	Page	Points	Score
Multiple Choice	3-7	200	
26) Reactions and Thermo	8	26	
27) Chemical Properties	9-10	35	
28) Acid-Base Chemistry	11	24	
29) Hydrogen Fuel Cell	12-13	35	
30) Nuclear Chemistry	14-15	30	
Total		**350**	

$E = mc^2$
$E = h\nu$
$\lambda\nu = c$
$\lambda_{deBroglie} = h / p = h / mv$
$E_{kin}(e-) = h\nu - \Phi = h\nu - h\nu_0$

$$E_n = -\frac{Z^2}{n^2} R_\infty$$

$$E_{i \to f} = -R_\infty\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$\Delta x\, \Delta p \geq h/4\pi$
$p = mv$

$PV = \text{constant}$
$PV = nRT$

$$E_{kin} = \frac{3}{2} RT$$

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$\Delta E = q + w$
$w = -P_{ext}\Delta V$

$$\Delta E = \frac{3}{2} nR\Delta T$$

$N_0 = 6.02214 \times 10^{23}\ mol^{-1}$

$R_\infty = 2.179874 \times 10^{-18}\ J$

$R_\infty = 3.28984 \times 10^{15}\ Hz$

$k = 1.38066 \times 10^{-23}\ J\ K^{-1}$

$h = 6.62608 \times 10^{-34}\ J\ s$

$m_e = 9.101939 \times 10^{-31}\ kg$

$c = 2.99792 \times 10^8\ m\ s^{-1}$

Gas Constant:

$R = 8.31451\ J\ K^{-1}\ mol^{-1}$

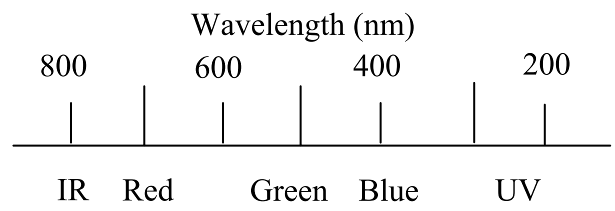
$R = 8.20578 \times 10^{-2}\ L\ atm\ K^{-1}\ mol^{-1}$

T (K) = T (C) + 273.15

F = 96,485 C / mol

1 V = 1 J / C
1 nm = 10^{-9} m
1 kJ = 1000 J
1 J = kg $m^2\ s^{-2}$
1 atm = 760 mmHg = 101,325 Pa
1 atm L = 101.3 J

Color and Wavelength of Light



$\Delta G° = \Delta H° - T\Delta S°$

$\Delta H° = \sum \Delta H°_f\ (\text{products}) - \sum \Delta H°_f\ (\text{reactants})$

$\Delta S° = \sum S°\ (\text{products}) - \sum S°\ (\text{reactants})$

$\Delta G° = \sum \Delta G°_f\ (\text{products}) - \sum \Delta G°_f\ (\text{reactants})$

$S = k_B \ln W$

$\Delta G° = -RT\ln K$

$$\ln K = -\frac{\Delta H°}{R}\frac{1}{T} + \frac{\Delta S°}{R}$$

$\Delta G° = -nF\Delta\mathcal{E}°$

$pX = -\log X$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

Heat Capacity of $H_2O(l)$ = 4.184 $Jg^{-1}K^{-1}$
Density of water = 1.00 g/mL

$N_t = N_0 e^{-\lambda t}$
$t_{1/2} = \ln(2)/\lambda$

For $y = ax^2+bx+c$, $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Standard Reduction Potentials	**E°(V)**
$Cl_2(l) + 2e- \to 2Cl-(aq)$	1.36
$Br_2(l) + 2e- \to 2Br-(aq)$	1.09
$Ag^+(aq) + e- \to Ag(s)$	0.80
$Cu^{2+}(aq) + 2e- \to Cu(s)$	0.34
$2H^+(aq) + e- \to H_2(g)$	0.00
$Pb^{2+}(aq) + 2e- \to Pb(s)$	-0.13
$Sn^{2+}(aq) + 2e- \to Sn(s)$	-0.14
$Ni^{2+}(aq) + 2e- \to Ni(s)$	-0.23
$Co^{2+}(aq) + 2e- \to Co(s)$	-0.28
$Cd^{2+}(aq) + 2e- \to Cd(s)$	-0.40
$Zn^{2+}(aq) + 2e- \to Zn\ (s)$	-0.76
$Li^+(aq) + e- \to Li(s)$	-3.04

Multiple Choice Questions (8 points each)

1) In lab, the reaction of acetic acid and sodium bicarbonate produced $CO_2(g)$ to inflate your airbag.

$$CH_3COOH(aq) + NaHCO_3(s) \rightarrow CH_3COO^{-}Na^{+}(aq) + CO_2(g) + H_2O(l)$$

If 53 g of $CH_3COOH(aq)$ is mixed with $NaHCO_3(s)$ to produce 7.2 g of water, what is the limiting reactant?

A) CH_3COOH
B) $NaHCO_3$
C) CO_2
D) H_2O
E) $CH_3COO^{-}Na^{+}$

2) Consider a two-slit experiment using monochromatic light. Which statements are true? (Mark all that apply.)

A) Constructive interference results in bright spots.
B) Constructive interference results in dimmed or no intensity.
C) Changing the frequency of light affects the interference pattern.
D) Destructive interference results in dimmed or no intensity.
E) Destructive interference results in bright spots.

3) In a hydrogen atom, which of the following arrangements of the electron and the proton has the lowest energy?

A) The electron is infinitely spaced from the proton.
B) The ground state.
C) The excited state.
D) The nucleus.
E) None of the above.

4) How many total isomers (structural and stereo) are there for $C_2Cl_2F_2$?

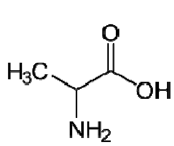
A) $\boxed{3}$ B) 5 C) 4 D) 2 E) 6

5) Which of the following molecules does not have a dipole moment?

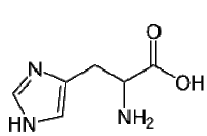
A) PF_3 B) BCl_2F C) CH_3OH D) Cl_2O $\boxed{\text{E) } XeCl_2}$

6) Which of the following amino acids is NOT chiral?

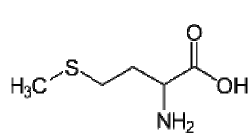
A)



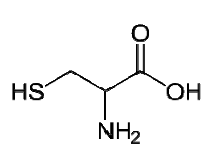
B)



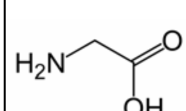
C)



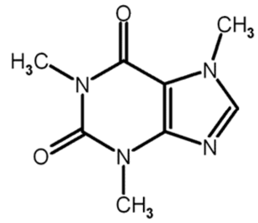
D)



E)

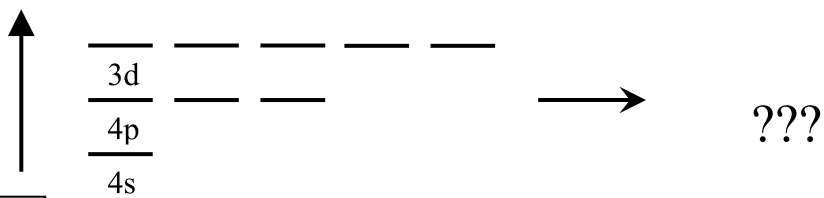


7) How many sigma bonds are present in the caffeine?

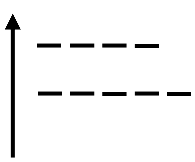


A) 27 B) 28 $\boxed{\text{C) 25}}$ D) 23 E) 24

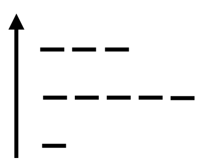
8) Which is the energy diagram for the arsenic hybrid atomic orbitals in AsF_5 after hydridization?



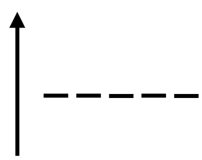
A)



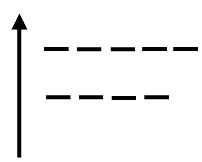
B)



C)



D)



E) None of these

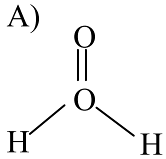
9) The decomposition of H_2O_2 is exothermic:

$$H_2O_2(g) \rightarrow H_2O + \tfrac{1}{2} O_2$$

	Average Bond Enthalpies (kJ mol^{-1})
O-H	463
O-O	146
O=O	497

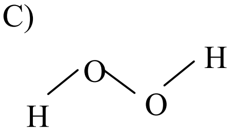
Using the bond energy data above, what is the molecular structure of H_2O_2?

A)



B) H— O=O— H

C)



D) Cannot be determined

E) None of these

10) A reaction will occur spontaneously at standard conditions if:

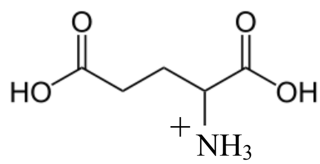
A) $\Delta H > 0$ B) $\Delta S > 0$ C) $\Delta G > 0$ $\boxed{\text{D) } K > 1}$ E) $\Delta H < 0$

11) A 30.0 g bar of iron (Fe) is heated to 106.0°C and then placed in a calorimeter with 100.0 g of 20.8°C water. The final temperature of the water is 23.4°C. What is the heat capacity of the Fe in J g^{-1} K^{-1}?

A) 439 B) -439 C) -0.439 $\boxed{\text{D) } 0.439}$ E) -39.9

12) Glutamic acid in acidic solution has the following structure. The pK_a of the protons are indicated in the figure.

$pK_a = 4.1$



$pK_a = 2.1$

$^{+}NH_3$

$pK_a = 9.5$

What is the total effective charge on glutamic acid at pH = 7.0?

A) -2 $\boxed{\text{B) } -1}$ C) 0 D) 1 E) 2

13) Which of the following will oxidize Co, but not Br- under standard conditions?

A) Cl_2 (g) B) Ag (s) $\boxed{\text{C) } Pb^{2+}}$ D) Li^+ E) None of these.

14) What is the standard cell potential for the following reaction?

$$Ni(s) + 2Ag^+(aq) \rightarrow Ni^{2+}(aq) + 2Ag(s)$$

A) -1.03 B) 0.57 C) -0.57 D) 1.83 $\boxed{\text{E) } 1.03}$

15) 112 J of work is used to compress a sample of xenon, while 64 J is applied as heat. What is the total change in internal energy of the system?

A) $\boxed{\text{176 J}}$
B) -176 J
C) 48 J
D) -48 J
E) cannot be determined

16) Ammonia, NH_3, is a weak base with a K_b of 1.8 x 10^{-5}. What is the pH of a 1.2 M solution of ammonia?

A) 2.3 B) 5.7 C) 9.8 $\boxed{\text{D) } 11.7}$ E) 13.4

17) The K_a of propionic acid is 1.34×10^{-5}. What is the pH at ½ equivalence?

A) 9.12
B) 11.2
C) $\boxed{4.87}$
D) 2.80
E) cannot be determined

18) Which half-cell reaction occurs at the anode in the following reaction?

$$Sn^{2+}(aq) + Ni(s) \rightarrow Sn(s) + Ni^{2+}(aq)$$

A) $Sn(s) \rightarrow Sn^{2+}(aq) + 2e-$
B) $Sn^{2+}(aq) + 2e- \rightarrow Sn(s)$
C) $Ni^{2+}(aq) + 2e- \rightarrow Ni(s)$
D) $\boxed{Ni(s) \rightarrow Ni^{2+}(aq) + 2e-}$
E) $Ni^{4+}(aq) + 2e- \rightarrow Ni^{2+}(aq)$

19) Which of the following reactions favors products *as written*?

A) $Zn^{2+}(aq) + 2e- \rightarrow Zn(s)$
B) $Cd^{2+}(aq) + Sn(s) \rightarrow Sn^{2+}(aq) + Cd(s)$
C) $Zn^{2+}(aq) + Cu(s) \rightarrow Cu^{2+}(aq) + Zn(s)$
D) $\boxed{Ag^{+}(aq) + e- \rightarrow Ag(s)}$
E) $Zn^{2+}(aq) + Cd(s) \rightarrow Cd^{2+}(aq) + Zn(s)$

20) Which of the following is the strongest oxidizing agent?

A) Sn^{2+} B) Cu C) Zn^{2+} $\boxed{\text{D) } Cu^{2+}}$ E) Ni^{2+}

21) What type of particle is emitted upon the decay of ${}^{122}_{53}I$ to ${}^{122}_{54}Xe$?

A) Positron
B) $\boxed{\text{Beta}}$
C) ${}^{4}_{2}He^{2+}$
D) Alpha
E) Gamma

22) Which of the following is the missing product in the fission reaction below?

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + \_\_\_\_\_\_\_\_ + 3\,{}^{1}_{0}n$$

A) ${}^{92}_{35}Br$ B) ${}^{92}_{37}Rb$ C) ${}^{91}_{36}Kr$ D) ${}^{91}_{35}Br$ $\boxed{\text{E) } {}^{92}_{36}Kr}$

23) Two isotopes of hydrogen, deuterium ($^{2}_{1}H$) and tritium ($^{3}_{1}H$), react in a fusion reaction to form a neutron ($^{1}_{0}n$) and which of the following?

A) $^{5}_{2}He$ B) $^{5}_{3}Li$ $\boxed{\text{C) } ^{4}_{2}He}$ D) $^{6}_{2}H$ E) $^{4}_{1}H$

24) What is the change in energy a positron annihilates an electron? (Mass of positron = mass of electron = 5.48 x 10^{-4} amu = 9.11 x 10^{-31} kg)

A) 1.02 keV
B) 5.10 x 10^{5} eV
C) 8.0 x 10^{-14} J
D) $\boxed{1.6 \text{ x } 10^{-13} \text{ J}}$
E) Cannot be determined

25) Who is the main discoverer of Americium?

A) E. McMillan and G.T. Seaborg
B) E.O. Lawrence
C) G.T. Seaborg
D) E. McMillan
E) None of these

Short Answer Questions

26) Reactions and Thermodynamics (26 points)

Consider the reaction $NH_3(g) + BF_3(g) \rightarrow NH_3BF_3(s)$.

a) Draw the Lewis Dot structure for the product of this reaction and indicate formal charges on nitrogen and boron. Explain why these two molecules tend to react.

Boron has a complete octet. If N shares it's lone pairs then both B and N have complete octets.

b) How does the root mean square velocity of NH_3 compare with BF_3? Show work to justify your answer. Circle your answer.

$NH_3 < BF_3$ $NH_3 = BF_3$ $\boxed{NH_3 > BF_3}$

The root mean square is larger for NH_3 since it has a heavier mass and v_{rms} is inversely proportional to the square root of molar mass via the following equation:

$v_{rms} = \sqrt{\frac{3RT}{M}}$. For BF_3, v_{rms} = 331 m/s and for NH_3, v_{rms} = 661 m/s

c) In the table below, place an X in the boxes that correspond to true statements for the formation reaction of NH_3BF_3.

	ΔH	ΔS
> 0		
< 0	X	X

d) Under what temperature (T) conditions does this reaction favor products? Circle your answer and clearly show all work.

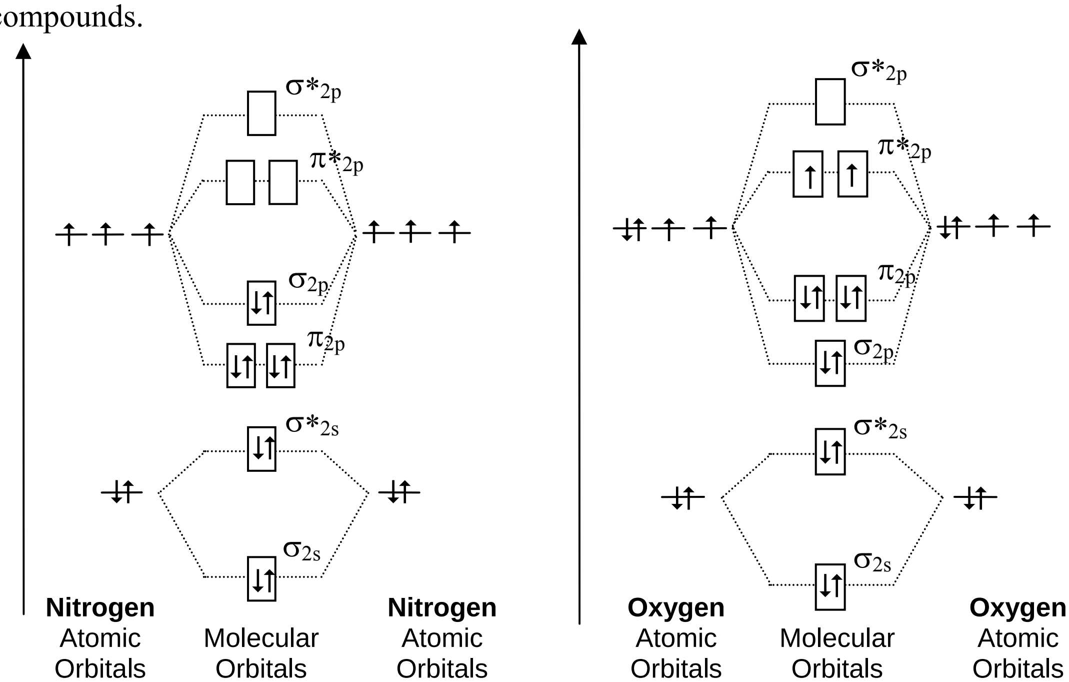
All T High T $\boxed{\text{Low T}}$ No T

Since both dH and dS are negative, only low T will favor products. This is seen in the following equation of dG = dH – TdS. The reaction will favor products when dG is less than zero.

27) Chemical Properties (35 points)

Lonnie demonstrated in lecture that N_2 and O_2 behave differently in the presence of a magnetic field.

a) Fill in the atomic and molecular orbital diagrams for each of these compounds.



b) Explain why O_2 was attracted to the large magnet, while N_2 was not.

O_2 is paramagnetic meaning it has unpaired electrons, while N_2 is diamagnetic with no unpaired electrons.

c) N_2 and O_2 can react to form NO, which is then oxidized to NO_2. Draw the Lewis dot structure for NO_2, including resonance if necessary. Identify the molecular and electronic geometry of NO_2.

Electronic Structure = _____Trigonal Planar____________________

Molecular Structure = _____Bent_______________________________

27) Chemical Properties (continued)

d) NO_2 is one of the pollutants that causes acid rain by the following reaction: $NO_2(g) + H_2O(l) \rightarrow HNO_2(aq) + HNO_3(aq)$. If the amount of $NO_2(g)$ in the atmosphere increased, what effect would this have on the concentrations of acid? Explain your answer.

This is Henry's Law or Le Chatelier's Principle. If we increase the pressure of $NO_2(g)$, then the concentration of $HNO_2(aq)$ and $HNO_3(aq)$ would increase.

28) Acid-Base Chemistry (24 points)
There are four flasks with 0.1M aqueous acidic solutions.

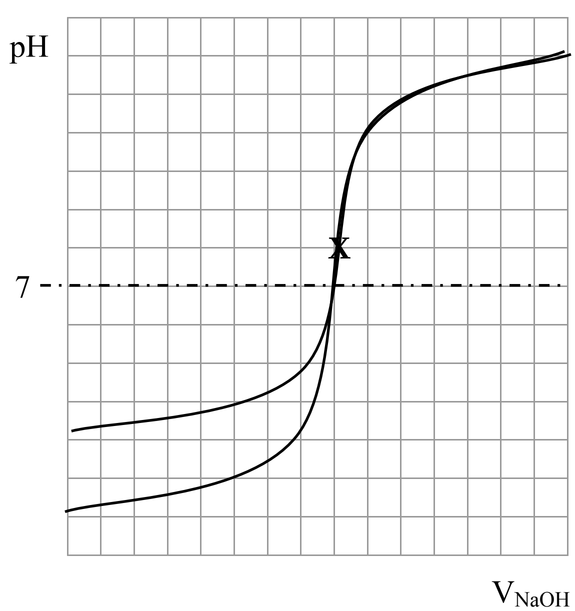
Flask A pH = 3.2 | Flask B pH = 5.0 | Flask C pH = 1.0 | Flask D pH = 4.1

a) Rank the acids in order of increasing acid ionization constant. K_a.
_____B______ < _____D_______ < ______A______ < ______C______

b) Formic acid, HCOOH, a weak acid, is found in ants. We want to determine the concentration of formic acid by titrating with sodium hydroxide, NaOH. Write out the chemical reaction indicating the acid/conjugate base and base/conjugate acid pairs.

$HCOOH + NaOH = HCOO^-Na^+ + H_2O$
Acid Base Conj. base Conj. acid

c) What would you expect the titration curve to look like for the titration of formic acid with a strong base, NaOH. Label the equivalence point of your titration curve with an X. For comparison the titration of HCl with NaOH is shown. You do not need to do extensive calculations.



29) Hydrogen Fuel Cell (35 points)

Given the current energy situation, alternatives to fossil fuels are receiving more consideration. One example is the hydrogen fuel cell in which hydrogen reacts with oxygen to produce water yielding an overall reaction equation of

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

The relevant half-cell reactions are:

$H_2(g) \rightarrow 2H^+(aq) + 2e-$ $\quad E° = 0.00$ V (at 25°C)

$O_2(g) + 4H^+(aq) + 4e- \rightarrow 2H_2O(l)$ $\quad E° = 1.23$ V (at 25°C)

a) Hydrogen is: (circle one)

Reduced $\quad$ $\boxed{\text{Oxidized}}$

b) Oxygen is: (circle one)

$\boxed{\text{Reduced}}$ $\quad$ Oxidized

c) Calculate the standard free energy for this fuel cell at 25°C. Show all work.

$E°_{cell} = 1.23$ V

$dG° = -nFE°_{cell} = -(4 \text{ moles})*(96485 \text{ C/mol})*(1.23 \text{ V})(1\text{J V}^{-1}\text{C}^{-1})$

$= -4.75 \times 10^5$ J

d) Calculate the equilibrium constant for this reaction at 25°C. Are products or reactants favored at equilibrium under standard conditions? Is this consistent with part (c)? Explain your answer.

dG = -RT*lnK

$K = e^{-dG/RT} = e^{-(-4.75 \times 105 \text{ J}/(8.31\text{J}/(\text{K*mol})*298 \text{ K})}$

$= 1.83 \times 10^{83}$, this is a very large K indicating that the products are strongly favored. This is consistent with the negative free energy of part (c).

e) The pressure of oxygen is 5 atm and the pressure of hydrogen is 10 atm at 25°C. In which direction will the reaction shift in order to regain equilibrium. Show all work and explain your reasoning.

We have K calculated above and here we can calculate Q. Q = 0.02, which is much less than K, so we would predict that the reaction will shift towards products to regain equilibrium.

30) Nuclear Chemistry (30 points)

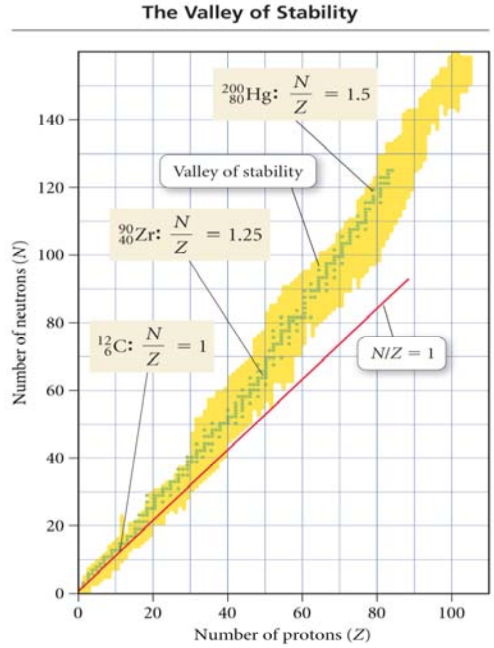
Nuclear chemistry is used to treat some forms of disease. For example, thyroid diseases can be treated using iodine-131 (I-131). Once absorbed, the radioisotope decays emitting beta particles that destroy the surrounding tissue.

a) Write the nuclear equation for this decay.

$${}^{131}_{53}I \rightarrow {}^{0}_{-1}e + {}^{131}_{54}Xe$$

b) Is beta decay consistent with what you would predict from comparing the number of neutrons to protons? Show work and explain.

The Valley of Stability



Near an atomic number of 53, the N/Z ratio is ~1.25. Calculating the N/Z ratio for I-131 results in a value of 1.47. This is clearly high compared to the "Valley of Stability" and the element can be stabilized if a neutron becomes a proton, thereby decreasing the N/Z ratio.

30) Nuclear Chemistry (continued)

c) A patient is given 125 mg of I-131, which has a half-life of 8 days. How much of the I-131 remains after 60 hours? Show all work.

60 hours = 2.5 days
$t_{1/2}$ = ln(2)/ k, k = 0.693/8 days = 0.0866 days -1
$N_t = N_0 * e^{-kt}$
= 155 mg*$e^{-0.0866/\text{days}*2.5\text{ days}}$
= 101 mg I-131 remains

d) In terms of ionizing power, which emitted particle poses a greater health hazard: alpha, beta, gamma. Explain your choice.

Alpha particles have the highest ionizing power and therefore would be the most dangerous to us IF ingested. However, alpha particles have the lowest penetrating power, so if we don't consume anything that decays via alpha emission, we are relatively safe from this particle.