This MC portion of the exam should have 22 questions. The point values are given with each question. Bubble in your answer choices on the bubblehseet provided. Your score is based on what you bubble on the bubblesheet and not what is circled on the exam.

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1 The nuclear binding energy is the amount of energy consumed during the following nuclear reaction: (2 pts)

✓ A. $^{16}_{8}O \longrightarrow 8\,^{1}_{0}n + 8\,^{1}_{1}H$

B. $8\,^{1}_{0}n + 8\,^{1}_{1}H \longrightarrow ^{16}_{8}O$

C. $^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{237}_{52}Te + ^{97}_{40}Zn + 2\,^{1}_{0}n$

D. $^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 2\,^{1}_{0}n$

Explanation: The nuclear binding energy is the amount of energy it takes to break the strong force between the nucleons of a nucleus.

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2 An unstable isotope of Ga-73 undergoes radioactive decay to Ga-73 and what? (4 pts)

✓ A. gamma radiation

B. beta radiation

C. alpha radiation

D. positron emission

Explanation: Since the charge and mass number are the same after the radioactive decay, the only type of emission that can occur is gamma radiation.

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3 Although alpha radiation is the most ionizing radiation because the nuclear charge is +2, it is the least damaging because: (4 pts)

✓ A. Alpha radiation is the least damaging to living things because it has relatively low energy and is absorbed by matter including smoke, thin sheets of paper and dead skin.

B. Alpha radiation is the least damaging to living things because it is not absorbed by anything, it just passes through all matter.

C. Alpha radiation is the least damaging to living things because it is made of helium and helium is an inert gas.

D. Alpha radiation is the least damaging to living things because it carries a positive charge, and that charge cannot cause ionization.

Explanation: Alpha radiation is a relatively large particle that picks up electrons which are readily available in any form of matter. This slows the nuclide and renders it a 0 net charge, which eliminates it's ionizing potential.

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4 Positrons are: (2 pts)

✓ A. high energy positively charged beta particles

B. low energy negatively charged beta particles

C. low energy positively charged protons

D. high energy positively charged protons

E. high energy negatively charged beta particles

Explanation: Positrons are high energy positively charged particles that have the same mass but opposite charge as high energy electrons ejected from the nucleus upon radioactive decay.

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5 Given that 0.1 percent of the mass of a sample of fissionable material is converted to energy upon nuclear fission. Estimate the amount of energy released upon the fission of 5 kg of Pu-239. (4 pts)

✓ A. 4.5×10^{11} kJ

B. 4.5×10^{14} kJ

C. 1.5×10^{4} kJ

D. 1.5×10^{7} kJ

Explanation: $\Delta E = \Delta m \cdot c^2$ where $\Delta m = 0.005$ kg

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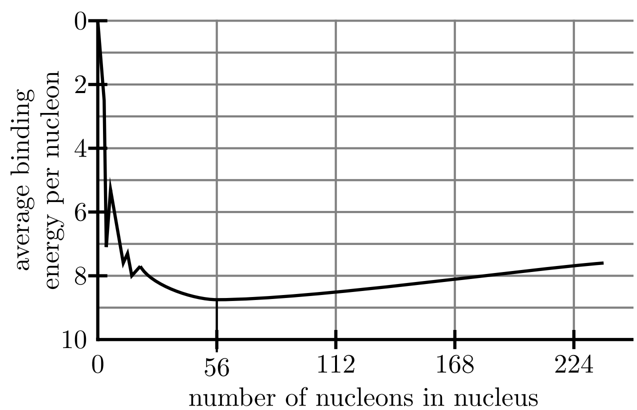
6 Observe the graph of the binding energy per nucleon shown to the right. Based on the graph, which of the following statements is true? (4 pts)



✓ A. One should expect that fusion type reactions that occur with nuclides with less than 56 nucleons should be exothermic.

B. One should expect that fission type reactions that occur with nuclides with less than 56 nucleons should be exothermic.

C. One should expect that fusion reactions that occur with nuclides with more than 56 nucleons should be exothermic.

D. One should expect that fission reactions that occur with nuclides with more than 56 nucleons should be endothermic.

Explanation: 56 nucleons is the lowest nuclide (iron) on the graph which means the most stable because it has the most binding energy per nucleon. One would expect lighter elements to combine (fusion) to form lower energy heavier nuclides, thereby releasing energy and heavier atoms will undergo fission to result in a lower energy, thus giving off energy in the change.

7 Ionizing radiation is the type of radiation that: (4 pts)

✓ A. Contains enough energy to ionize atoms and break chemical bonds.

B. Must contain gamma radiation.

C. Must contain a nuclear particle and gamma radiation.

D. Must contain x-rays.

Explanation: Ionizing radiation causes atoms and/or molecules to ionize and possibly break chemical bonds.

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8 The half-life of I-131 is 8 days. After 24 days ______ of the original amount of I-131 remains. (4 pts)

A. One half

B. One third

C. One fourth

✓ D. One eighth

E. One sixteenth

Explanation: 24 days is three half-lives. After the first half-life, one half remains. After the second half-life, half of that, or overall one fourth remains, and so on.

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9 Fill in the blanks to correctly compare nuclear and chemical reactions. Energy changes are much larger in ______ .

Mass changes ~~cannot~~ **can** be detected in ______ . (2 pts)

A. nuclear reactions; both types of reactions.

B. chemical reactions; both types of reactions.

C. chemical reactions; chemical reactions but not in nuclear reactions.

D. nuclear reactions; chemical reactions but not in nuclear reactions.

E. chemical reactions; nuclear reactions but not in chemical reactions.

✓ F. nuclear reactions; nuclear reactions but not in chemical reactions.

Explanation: The energy changes in nuclear reactions are large compared to those in chemical reactions. In nuclear reactions, small amounts of mass can be converted to energy according to the equation $E = mc^2$. Although chemical reactions are equally reliant on this mass/energy equation, the quantities of mass are so much smaller that the mass differences are not detectable.

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10 The reaction

$$NH_4^+(aq) + NO_2^-(aq) \longrightarrow N_2(g) + 2H_2O(\ell)$$

is first order in ammonium ion and first order in nitrite ion. What are the units for the rate constant? (2 pts)

A. M s^{-1}

✓ B. M^{-1} s^{-1}

C. M^{-1}

D. s^{-1}

E. M^{-2} s^{-1}

Explanation: The reaction is second order overall. $rate = k[NH_4^+][NO_2^-]$ In order to get the desired M/s units for rate, k must have units of M^{-1} s^{-1}.

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11 A certain reaction has an activation energy of 300 kJ/mol. As you increase the temperature the reaction rate will ______ and the activation energy will ______ . (4 pts)

A. increase; increase

B. increase; decrease

✓ C. increase; stay the same

D. decrease; increase

E. decrease; decrease

F. decrease; stay the same

Explanation: Reaction rates increase with temperature because more molecules have enough energy to make it over the activation energy barrier.

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12 For the reaction

$$2N_2O_5(g) \longrightarrow 4NO_2(g) + O_2(g)$$

The activation energy is 1.0×10^5 J/mol and the value of k at 20°C is 2.0×10^{-5} s^{-1}. What is the value of k at 30°C? (4 pts)

A. 2.0×10^{-5} s^{-1}

B. 2.0×10^{-6} s^{-1}

C. 8.4×10^{-13} s^{-1}

D. 9.3×10^{-4} s^{-1}

✓ E. 7.3×10^{-5} s^{-1}

Explanation: As temperature increases, the rate constant increases. Use the Arrhenius equation to calculate the new rate constant.

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13 The reaction A + B $\longrightarrow$ 2C has the rate equation $rate = k[A]^2$. Which is NOT true about this reaction? (4 pts)

A. Increasing the temperature would increase the reaction rate.

✓ B. The mechanism for this reaction could have only a single-step.

C. Increasing the concentration of reactant A will increase the reaction rate.

D. The reaction rate will remain constant even if you increase the concentration of reactant B.

Explanation: The reaction is first order in A and zeroth order in B, so the concentration of A will affect the rate of reaction but the concentration of B will not. If this reaction was an elementary, one-step reaction, the rate law would have to be $rate = k[A][B]$.

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14 A reaction with an activation energy of 75 kJ/mol takes 3 hours to reach completion when run at 25°C. At what temperature should this reaction be run in order to drop that time down to only 30 minutes? (4 pts)

A. 77°C

B. 150°C

C. 52°C

D. 37°C

✓ E. 44°C

Explanation: Use the Arrhenius equation knowing that the new temperature (T_2) will give a rate constant that is 6 times larger than the one at T_1. This is because 30 minutes is $1/6^{\text{th}}$ of 3 hours which means 6× faster. So $k_2/k_1 = 6$.

$$\ln 6 = \frac{75000}{8.314}\left(\frac{1}{298.15} - \frac{1}{T_2}\right)$$

Solving for T_2 gives 317 K which is the same as 44°C.

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15 Consider the gas phase reaction (constant volume) of the decomposition of nitroethane:

$$C_2H_5NO_2(g) \longrightarrow C_2H_4(g) + HNO_2(g)$$

At 610 K, the rate constant for this reaction is 2.1×10^{-4} s^{-1}. If the initial partial pressure of $C_2H_5NO_2$ is 80 torr, what will be its partial pressure after 2.5 hours? (4 pts)

✔ A. 12 torr

B. 77 torr

C. 31 torr

D. 9 torr

E. 18 torr

F. 26 torr

Explanation: The units for the rate constant (s^{-1}) will tell you that the reaction is first order. Solve first order rate equation with 80 torr as initial conc/press:

$$\ln 80/P = (2.1 \times 10^{-4})(2.5 \cdot 60 \cdot 60)$$

Solving for P will give you 12 torr.

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16 Consider the following reaction:

$$6\,NaOH \ + \ Al_2O_3 \ + \ 12\,HF \ \longrightarrow \ 2\,Na_3AlF_6 \ + \ 9\,H_2O$$

At a given time, water is being produced at a rate of 0.54 M/min for this reaction. What is the corresponding rate for HF during this time? (4 pts)

A. -0.54 M/min

✔ B. -0.72 M/min

C. -0.060 M/min

D. 0.54 M/min

E. 0.72 M/min

F. 0.060 M/min

G. -0.36 M/min

H. 0.36 M/min

Explanation: The stoichiometric ratio of HF to H_2O is 12/9. 12/9 times 0.54 is 0.72. HF is a reactant and must be the opposite in sign as the products, therefore the rate of change in HF is -0.72 M/min.

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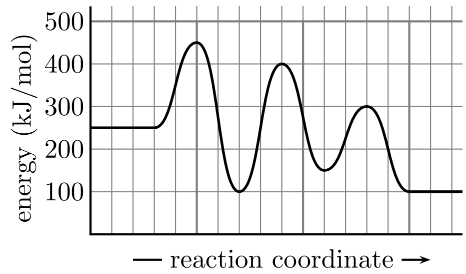
17 The potential energy diagram shown to the right is for a specific reaction scheme. How many steps are in the reaction mechanism and which step is the limiting step? (4 pts)



A. 2 steps , 2nd step limiting

B. 3 steps , 1st step limiting

C. 2 steps , 1st step limiting

✔ D. 3 steps , 2nd step limiting

E. 3 steps , 3rd step limiting

F. 1 step , 1st step limiting

Explanation: There are 3 maxima and that means 3 steps. The 2nd step (2nd peak) has the largest rise from base to peak (300 kJ) and therefore is the rate limiting step.

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18 Consider the following elementary reaction step that is a part of a kinetic mechanism:

$$C_3H_7I + NH_3 \rightarrow C_3H_7NH_3^+ + I^-$$

Classify the step type and give its predicted rate law. (4 pts)

✔ A. bimolecular, $rate = k[C_3H_7I][NH_3]$

B. unimolecular, $rate = k[C_3H_7I]$

C. bimolecular, $rate = k[C_3H_7I]^2$

D. bimolecular, cannot be determined from balanced equation

E. termolecular, $rate = k[C_3H_7I][NH_3][C_3H_7NH_3^+]^{-1}[I^-]^{-1}$

Explanation: the elementary step involves two molecules so this is a bimolecular step. The rate is predicted to be first order with respect to each molecule.

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19 The addition of a catalyst to a reaction will speed up the reaction by (4 pts)

✔ A. altering the mechanism and lowering the activation energy.

B. shifting the equilibrium to favor the products.

C. making the reaction more exothermic.

D. catalysts do not speed up reactions.

E. making the reaction more endothermic.

F. altering the mechanism and raising the activation energy.

G. shifting the equilibrium to favor the reactants.

Explanation: a catalyst alters the mechanism of a reaction and lowers the barrier of the rate limiting step.

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20 The decomposition of azomethane ($C_2H_6N_2$) follows first order kinetics with a rate constant of 40 min^{-1}. If you start with a concentration of 0.2 M $C_2H_6N_2$, what is the rate of the decomposition after 0.1 min? (4 pts)

✓ A. 1.46×10^{-1} M min^{-1}

B. 4 M min^{-1}

C. 4.46×10^{2} M min^{-1}

D. 0.4 M min^{-1}

E. 3.66×10^{-3} M min^{-1}

Explanation: the rate = k[$C_2H_6N_2$]. The [$C_2H_6N_2$]=[$C_2H_6N_2$]$_0 \times e^{-kt}$. [$C_2H_6N_2$] = (0.2) $\times$ e^{-4} = 3.66 $\times 10^{-3}$ M. The rate = k[$C_2H_6N_2$] = (40 min^{-1})(3.66 $\times 10^{-3}$M) = 1.46×10^{-1} M min^{-1}

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21 For the simple reaction, A $\rightleftharpoons$ B, if the forward rate constant k_1 is 100 s^{-1} and the backward rate constant k_{-1} is 0.01 s^{-1}, what can you say about the relative concentrations of A and B at equilibrium. (4 pts)

✓ A. The concentration of B is much greater than that of A.

B. The concentration of A is much greater than that of B.

C. The concentrations of A and B will be exactly equal.

D. It depends on the initial concentration of A.

E. It depends on the initial concentrations of A and B.

Explanation: The equilibrium constant is the ratio of the forward rate constant to the backward rate constant. $K = k_1/k_{-1}$. Since k_1 is much larger than k_{-1} the value of K will be much larger than 1 (it will in fact be 10^4). At equilibrium the ratio of [B]/[A] = $K = 10^4$.

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22 The reaction $NO_2 + CO \rightarrow NO + CO_2$ is found to obey the following empirical rate law: $rate = k[NO_2]^2$. For this reaction, if you start with an initial concentration of CO that is much higher than the initial concentration of NO_2 ($[CO]_0 >> [NO_2]_0$) then a plot of ln[NO_2] will appear (4 pts)

✓ A. curved as the kinetics are 2nd order in NO_2.

B. linear as the kinetics are 1st order in NO_2.

C. linear as the kinetics are pseudo-first order in NO_2.

D. curved as the kinetics are 1st order in NO_2.

Explanation: the kinetics are 2nd order in NO_2, therefore the plot of ln[NO_2] will be curved. The CO concentration has no effect on the kinetics.

- Make sure you complete the front and back of the free response portion.
- Remember to bubble in ALL your answers BEFORE time is called.
- Sign your exam, bubblesheet, AND free response page.
- Turn in ALL parts: exam copy, bubblesheet, and free response.