Chemistry 112-2010, Exam #3, April 28 NAME: __________________________

Questions 1-15 = 4 points each, no partial credit; Questions 16-20 = 8 points each, with partial credit

ANSWER BOTH SCANTRON and PAPER Hand in both.

1. When the reversible reaction, $N_2 + O_2 \rightleftarrows 2\ NO$, has reached a state of dynamic equilibrium, which statement below is true?

(a) Both the forward and reverse reactions stop completely and no more NO, N_2 or O_2 are produced.

(b) The rate of the forward reaction equals the rate of the reverse reaction.

(c) The rate constant of the forward reaction equals the rate constant of the reverse reaction.

2. Which of the following best favors a reaction having a fast rate?

(a) low activation energy

(b) high activation energy

(c) low activation energy and high temperature

(d) high activation energy and high temperature

(e) high activation energy and low temperature

(f) low activation energy, high temperature, and negative ΔH

3. For a reaction with the rate law: Rate = $k[A]$:

(a) a plot of ln[A] vs. time gives a straight line.

(b) a plot of 1/[A] vs. 1/time gives a straight line.

(c) a plot of [A] vs. time gives a straight line.

(d) a plot of 1/[A] vs. time gives a straight line.

(e) a plot of $\log \frac{[A]_o}{[A]}$ vs. 1/time gives a straight line.

4. The gas phase reaction $C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2$ follows the rate law: Rate = $k[C_2H_4]\,[Cl_2]^2$. If the concentration of C_2H_4 is doubled while the concentration of Cl_2 remains constant, the initial rate of the reaction:

(a) increases by a factor of 4.
(b) decreases by a factor of 2.
(c) increases by a factor of 2. because the reaction is first order in C2H4
(d) increases by a factor of 1.5.
(e) remains constant.

5. Use the following information for the reaction: 2A + B → C. Initial rates were measured at different molar concentrations.

Experiment	[A]	[B]	Initial Rate (mol/L·s)
1	1.0×10^{-2}	1.0×10^{-2}	5.3×10^{-4}
2	2.0×10^{-2}	1.0×10^{-2}	1.06×10^{-3}
3	3.0×10^{-2}	2.0×10^{-2}	1.59×10^{-3}
4	2.0×10^{-2}	2.0×10^{-2}	1.06×10^{-3}

What is the order of this reaction with respect to reactant [B]?

(a) Zero (b) One (c) Two (d) Three

The rate does not change when [B] changes.

6. What is a *half-life*?

(a) It is a special case when the rate constant equals one-half. (i.e. $k = 0.5$)

(b) A period of time required for the concentration of a reactant to reduce to one-half its original value.

(c) It is a rate law that is one-half order: (ie. Rate = $k[A]^{1/2}$)

(d) One half the time it takes for the reaction to go to completion.

(e) A period representing the amount of time required for an initial concentration of a reactant to reduce to 0.5 M.

7. Consider the system, $2\ CH_2Cl_2(g) \rightleftarrows CH_4(g) + CCl_4(g)$, which has an equilibrium constant of K = 2.4. If a system has:

$[CH_2Cl_2] = 0.22$ M
$[CH_4] = 1.64$ M
$[CCl_4] = 0.58$ M

then, (a) the system is at equilibrium

(b) the system is not at equilibrium and will react to form more CH_2Cl_2

(c) the system is not at equilibrium and will react to form more CH_4 and CCl_4

$Q = (1.64)(0.58)/(0.22)^2 = 19.7$; Q > K, so product concentrations are too high; reaction shifts left.

8. Iodine-123 is used to study thyroid gland function. This radioactive isotope breaks down in a *first order* process with a half-life of 13.1 hours. What is the rate constant, *k* for the process?

(a) 0.0529 hr^{-1} *(b)* 6.55 hr^{-1} *(c)* 9.08 hr^{-1} *(d)* 18.9 hr^{-1} *(e)* 26.2 hr^{-1}

for a first order reaction, k = 0.693/$t_{1/2}$

9. For the reaction 2 $SO_2Cl_2(g) \rightleftarrows 2 SO_2(g) + 2 Cl_2(g)$, the expression for K_{eq} is

(a) $$K_{eq} = \frac{[SO_2]^2[Cl_2]^2}{[SO_2Cl_2]^2}$$

10. The following system is at equilibrium $CH_4(g) + CCl_4(g) \rightleftarrows CH_2Cl_2(g)$.

If CCl_4 is removed from the sample, what will then happen to the concentrations of CH_4 and of CH_2Cl_2?

(a) both $[CH_4]$ and $[CH_2Cl_2]$ will increase

(b) both $[CH_4]$ and $[CH_2Cl_2]$ will decrease

(c) $[CH_4]$ will decrease and $[CH_2Cl_2]$ will increase

(d) $[CH_4]$ will increase and $[CH_2Cl_2]$ will decrease

(e) $[CH_4]$ will remain constant and $[CH_2Cl_2]$ will increase

Reaction shifts left to replenish the decreased CCl4.

11. What are $[H_3O^+]$ and $[OH^-]$ for a solution that has a pH of 9.0?

(a) $[H_3O^+] = 9$ M and $[OH^-] = 5$ M

(b) $[H_3O^+] = 5$ M and $[OH^-] = 9$ M

(c) $[H_3O^+] = 1 \times 10^{-9}$ M and $[OH^-] = 1 \times 10^{-5}$ M

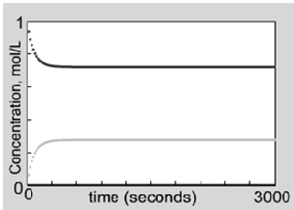
(d) $[H_3O^+] = 1 \times 10^{-5}$ M and $[OH^-] = 1 \times 10^{-9}$ M

(e) $[H_3O^+] = 1 \times 10^{9}$ M and $[OH^-] = 1 \times 10^{5}$ M

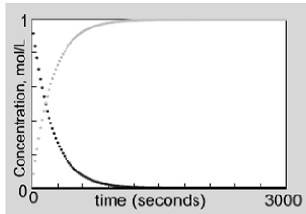
12. What is the conjugate base of $HC_2O_4^-$?

(a) $H_2C_2O_4$ ***(b) $C_2O_4^{2-}$*** (c) 2 CO_2 (d) $H_3C_2O_4^+$

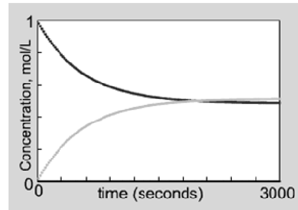
Questions 13-15 use the following concentration-time plots. The black line represents reactants and the light gray line represents products. Answer with the correct letter.



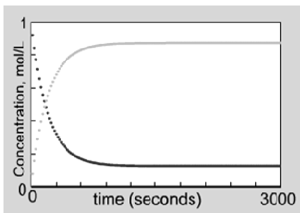
a.



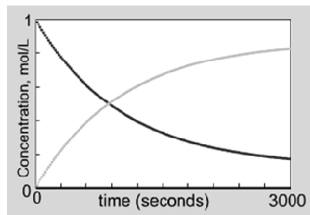
b.



c.



d.



e.

13. Which reaction goes to completion? B

14. Which reaction has the smallest equilibrium constant? A

15. Which reaction has an equilibrium constant of about 1 (K = 1)? C

For questions 16-20, your work MUST be shown. You must use the ICE method where noted. Partial credit for these problems will be given where appropriate.

16. The rate constant for a first order reaction at 773 K is 1.68 s^{-1}. The rate constant for this process at 873 K is 14.6 s^{-1}.

What is the activation energy for the reaction in kJ/mol? (R = 8.314 J/mol·K)

$$\ln\frac{14.6}{1.68} = -\frac{Ea}{R}\left[\frac{1}{873K} - \frac{1}{773K}\right]$$

$$2.162 = -\frac{Ea}{R}\left[-0.0001482\right]$$

$$Ea = \frac{2.162 \bullet 8.314 J/K}{0.0001482} = 121000J = 121kJ$$

17. A highly toxic pesticide decomposes in the soil via a *first order rate law*. The rate constant for the decomposition is 0.0995 days^{-1}. How long will it take for it to decompose to 10% of its original concentration? In days.

The key here is that $[R]_t/[R]_o = 0.10$

$\ln(0.10) = -kt$

$-2.303 = -0.0995\ \text{day}^{-1}\ t$

$t = 2.303/0.0995\ \text{days} = 23.1\ \text{days}$

18. Butene isomerizes to form isobutane.

butene ⇄ cyclobutane K = 6.0

If a sample of 1.00 M butene is placed in a flask and allowed to react, what will [cyclobutane] be once equilibrium is established?

Show your work, the ICE method must be used and presented correctly.

	butene	⇄	*cyclobutane*
Initial	*1.00*		*0*
Change	*-x*		*+x*
Equilibrium	*1.00 –x*		*x*

$$K = 6.0 = \frac{x}{1.0 - x}$$

$6.0(1.0-x) = x$

$6.0 - 6.0x = x$

$6.0 = 7x$

$x = 6/7 = 0.857 = [\text{cyclobutane}]$

19. What is the pH of a 0.30 M solution of CH_3CO_2H? $K_a = 1.8 \times 10^{-5}$

Show your work, the ICE method must be used and presented correctly.

This is a standard weak acid equilibrium case.

	$CH_3CO_2H + H_2O$	$\rightleftarrows$	H_3O^+	+	$CH_3CO_2^-$
initial	*0.30*		*0*		*0*
change	*-x*		*+x*		*+x*
Equilibrium	*0.30 – x*		*x*		*x*

$$K = 1.8\times10^{-5} = \frac{[H_3O^+][CH_3CO_2^-]}{[CH_3CO_2H]} = \frac{x^2}{0.30-x} \approx \frac{x^2}{0.30}$$

$$x = \sqrt{0.30\bullet1.8\times10^{-5}} = 0.00232M = [H_3O^+]$$

pH = -log(0.00232) = 2.63

20. Consider the reaction, $C_3H_6ClOH(aq) \rightarrow C_3H_5OH(aq) + HCl(aq)$ which is first order in C_3H_6ClOH with a rate constant of 0.125 min^{-1}. If the reaction is started with $[C_3H_6ClOH]$ = 0.88 M, what will the pH be after 15 minutes?

This problem requires you to determine how much C_3H_6ClOH reacts in 15 minutes. That then will tell you how much HCl is produced. That, in turn tells the pH.

$[C_3H_6ClOH]_{15min} = 0.88\ M\ e^{-(0.125)(15)} = 0.135\ M$

The change in $[C_3H_6ClOH]$ = 0.88 M – 0.135 M = 0.745 M

Each C_3H_6ClOH that reacts produces one HCl, so, $[HCl]_{15\ min} = 0.745$.

$[H_3O^+] = 0.745$;   *pH = 0.128*

pH = ________

hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 * *	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

*Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
* *Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]