



## Information

For the reaction  $aA + bB \rightleftharpoons cC + dD$

$$\text{rate} = -\frac{1}{a} \frac{\Delta[A]}{\Delta t} = -\frac{1}{b} \frac{\Delta[B]}{\Delta t} = +\frac{1}{c} \frac{\Delta[C]}{\Delta t} + \frac{1}{d} \frac{\Delta[D]}{\Delta t}$$

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

1<sup>st</sup> order reactions:

$$\ln[A]_t = -kt + \ln[A]_0$$

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

2<sup>nd</sup> order reactions:

$$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

Arrhenius

$$\ln k = -(E_a/RT) + \ln A$$

$$\ln(k_1/k_2) = E_a/R(1/T_2 - 1/T_1)$$

$$R = 8.314 \text{ J}/(\text{mol}\cdot\text{K})$$

$$K_p = K_c(RT)^{\Delta n}$$

$$R = 0.0821 \text{ L}\cdot\text{atm}/(\text{mol}\cdot\text{K})$$

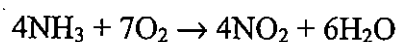
$$K_a = \frac{[H^+][X^-]}{[HX]}, \quad K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

$$K_a \times K_b = K_w, \quad pK_a + pK_b = pK_w = 14.00$$

(1) Of the following, only \_\_\_\_\_ are not valid units for a reaction rate

- a) mol/L
  - b) M/s
  - c) mol/hr
  - d) g/s
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(2) Which substance in the reaction below either appears or disappears the fastest?



- a)  $\text{NH}_3$
  - b)  $\text{O}_2$
  - c)  $\text{NO}_2$
  - d)  $\text{H}_2\text{O}$
  - e) The rates of appearance/disappearance are the same for all of these.
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(3) The rate law of a reaction is  $\text{rate} = k[\text{A}]^x$ . The units of  $k$ , if the reaction is second order in A, are \_\_\_\_

- a) M/s
- b)  $\text{M}^{-1}\text{s}^{-1}$
- c) 1/s
- d) 1/M
- e)  $\text{s}/\text{M}^2$

$$\text{rate} = k[\text{A}]^2$$

$$\frac{\text{M}}{\text{s}} = k \cdot \text{M}^2$$

$$k = \frac{\text{rate}}{[\text{A}]^2}$$

$$k = \frac{\text{M} \cdot \text{s}^{-1}}{\text{s} \cdot \text{M}^2} = \frac{\text{L}}{\text{M} \cdot \text{s}}$$

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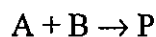
(4) A reaction was found to be third order in A. Increasing the concentration of A by a factor 3 will cause the reaction rate to \_\_\_\_

- a) remain constant
- b) increase by a factor of 27
- c) increase by a factor 9
- d) triple
- e) decrease by a factor of the cube root of 3

$$\text{rate} = k[\text{A}]^3$$

$$\text{rate} = k(3 \cdot [\text{A}])^3 = 27 k[\text{A}]^3$$

(5) Use the information below to determine the order of the reaction in reactant B.



Experiment Number	[A] (M)	[B] (M)	Initial Rate (M/s)
1	0.273	0.763	2.83
2	0.273	1.526	2.83
3	0.819	0.763	25.47

- a) 1
- b) 2
- c) 3
- d) 4
- e) 0

$$\begin{aligned} \text{rate}_1 &= k[A_1]^n[B_1]^m \\ \text{rate}_2 &= k[A_2]^n[B_2]^m \end{aligned} \quad \left| \quad \frac{\text{rate}_1}{\text{rate}_2} = 1 = \frac{k[A_1]^n[B_1]^m}{k[A_2]^n[B_2]^m} \right.$$

$$1 = \left(\frac{0.763}{1.526}\right)^m \text{ only if } m=0 \quad [A_1]=[A_2]$$

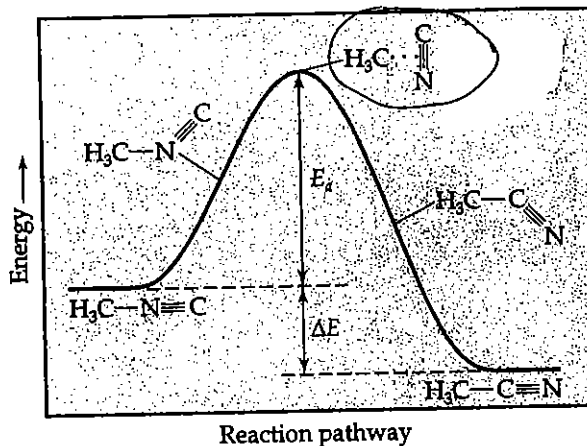
(6) The reaction  $A \rightarrow B$  is first order in  $[A]$ . The half-life of this reaction is \_\_\_\_ s.

Time (s)	[A] (M)
→ 0.0	1.60
→ 5.0	0.80 $\rightarrow 1/2$ initial
10.0	0.40
15.0	0.20
20.0	0.10

- a) 23
- b) 10.0
- c) 5.0
- d) 0.20
- e) -5.0

(7) In the potential energy profile of a reaction, the species that exists at the maximum on the curve is called the \_\_\_\_\_

- a) product
- b) activated complex
- c) activation energy
- d) enthalpy of reaction
- e) atomic state

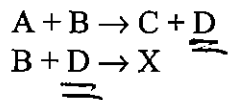


(8) In general, as temperature goes up, reaction rate \_\_\_\_\_

- a) goes up if the reaction is exothermic
- b) goes up if the reaction is endothermic
- c) goes up regardless of whether the reaction is exothermic or endothermic
- d) stays the same regardless of whether the reaction is exothermic or endothermic
- e) stays the same if the reaction is first order

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(9) The mechanism for formation of the product X is:



The intermediate reactant in the reaction is \_\_\_\_\_

- a) A
- b) B
- c) C
- d) D
- e) X

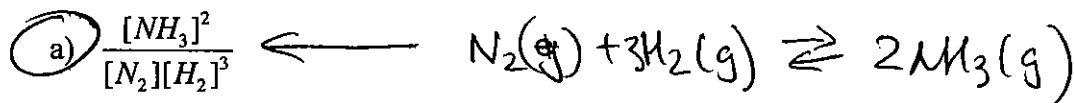
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(10) At equilibrium, \_\_\_\_\_

- a) all chemical processes have ceased
- b) the rate of the forward reaction equals that of the reverse
- c) the rate constant for the forward reaction equals that of the reverse
- d) none of the above

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(11) Which is the correct equilibrium constant expression for the Haber process (production of ammonia gas from nitrogen and hydrogen gases)?



- b)  $\frac{[NH_3]}{[N_2][H_2]}$
- c)  $\frac{[H_2]^3}{[N_2][NH_3]^2}$
- d)  $\frac{[N_2][H_2]^3}{[NH_3]^2}$
- e)  $\frac{[N_2]^2[H_2]^3}{[NH_3]}$

- (12) Consider the gaseous equilibrium:  $2A \rightleftharpoons 2B + C$   
 Determine the value of the missing B concentration at equilibrium

Exp#	[A] at equilibrium	[B] at equilibrium	[C] at equilibrium
1	0.10 M	0.15 M	0.20 M
2	0.20 M	0.50 M	0.072 M
3	0.35 M	?	0.15 M

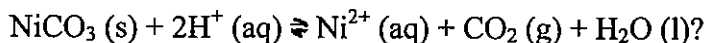
- a) 0.37  
 b) 0.35  
 c) 0.40  
 d) 0.61  
 e) 0.20

$$K_c = \frac{[B]^2 [C]}{[A]^2} \quad \# \quad K_c = \frac{(0.15)^2 \cdot (0.20)}{(0.10)^2} = 0.45$$

$$[B]_3^2 = \frac{K_c \cdot [A_3]^2}{[C]} = \frac{(0.45)(0.35)^2}{(0.15)} = 0.37$$

$$[B] = \sqrt{0.37} = 0.61$$

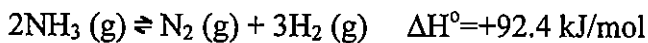
- (13) Which of the reactants and/or products do not appear in the properly written heterogeneous  $K_c$  expression for the reaction:



- a)  $NiCO_3 (s)$  only  
 b)  $CO_2 (g) + H_2O (l)$   
 c)  $H^+ (aq)$  and  $Ni^{2+} (aq)$   
 d)  $CO_2 (g)$  only  
 e)  $NiCO_3 (s)$  and  $H_2O (l)$

$$K_c = \frac{[Ni^{2+}][CO_2]}{[H^+]^2}$$

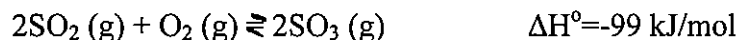
- (14) Consider the following reaction at equilibrium:



Adding  $N_2 (g)$  to the system at equilibrium will \_\_\_\_\_

- a) decrease the concentration of  $NH_3 (g)$  at equilibrium  
 b) decrease the concentration of  $H_2 (g)$  at equilibrium  
 c) increase the value of the equilibrium constant  
 d) cause the reaction to shift to the right  
 e) remove all of the  $H_2 (g)$

(15) Consider the following reaction at equilibrium:



If the temperature is increased, then \_\_\_\_\_ when the total pressure is held constant

- a) the concentration of  $\text{SO}_3$  will decrease
  - b) the partial pressure of  $\text{SO}_2$  will decrease
  - c) the total volume of the system will decrease
  - d) the partial pressure of  $\text{O}_2$  will decrease
- 

(16) The effect of a catalyst on a chemical reaction is to \_\_\_\_\_

- a) lower the energy of the transition state
  - b) accelerate the forward reaction only
  - c) make reactions more exothermic
  - d) increase the entropy change associated with a reaction
  - e) react with product, effectively removing it and shifting the equilibrium to the right
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(17) According to Arrhenius, an acid is a substance that \_\_\_\_\_

- a) is capable of accepting one or more  $\text{H}^+$
  - b) causes an increase in the concentration of  $\text{H}^+$  in aqueous solutions
  - c) can accept a pair of electrons to form a coordinate covalent bond
  - d) reacts with the solvent to form the cation formed by autoionization of that solvent
  - e) tastes bitter
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(18) Which one of following is not a Bronsted-Lowry acid?

- a)  $(\text{CH}_3)_3\text{NH}^+$
- b)  $\text{CH}_3\text{COOH}$
- c)  $\text{HF}$
- d)  $\text{HNO}_2$
- e)  $\text{ClO}_4^-$

(19) A substance that is capable of acting as both acid and as base is \_\_\_\_\_

- a) autosomal
  - b) conjugated
  - c) amphoteric
  - d) autocratic
  - e) contrapunctal
- 

(20) The concentration of water in pure water is approximately \_\_\_\_\_ M

- a) 18
- b) 100
- c) 55
- d) 0.100
- e) 83

$$[\text{H}_2\text{O}] \approx \frac{1000 \frac{\text{g}}{\text{L}}}{18 \frac{\text{g}}{\text{mol}}} = \frac{1000}{18} \text{ M} \approx 55 \text{ M}$$

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(21) The conjugate base of  $\text{HSO}_4^-$  is

- a)  $\text{OH}^-$
  - b)  $\text{H}_2\text{SO}_4$
  - c)  $\text{SO}_4^{2-}$
  - d)  $\text{HSO}_4^+$
  - e)  $\text{H}_3\text{SO}_4^+$
- 

(22) The molar concentration of hydroxide ion ( $\text{HO}^-$ ) in pure water at  $25^\circ \text{C}$  is

- a) 1
  - b) 0
  - c)  $1 \times 10^{-14}$
  - d)  $1 \times 10^{-7}$
  - e) 7
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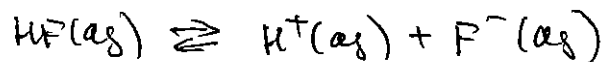
(23) What is the pH of a 0.015 M solution of  $\text{Ca}(\text{OH})_2$

- a) 12.48
- b) 12.18
- c) 1.82
- d) 10.35
- e) 1.52

$$\begin{aligned} \text{Ca}(\text{OH})_2(\text{aq}) &\rightleftharpoons \text{Ca}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \\ [\text{OH}^-] &= 0.030 \text{ M} \quad \text{pOH} = -\log [\text{OH}^-] = 1.52 \\ \text{pH} &= 14.00 - 1.52 = 12.48 \end{aligned}$$

(24) The  $K_a$  of HF is  $6.8 \times 10^{-4}$ . What is the pH of a 0.35 M solution of HF?

- a) 3.17
- b) 1.81
- c) 3.62
- d) 0.46
- e) 12.19



$$K_a = \frac{[\text{H}^+][\text{F}^-]}{[\text{HF}]} = \frac{(x)(x)}{(0.35-x)} = 6.8 \times 10^{-4}$$

$$x^2 = 0.35 \cdot 6.8 \times 10^{-4} = 2.38 \times 10^{-4}; \quad x \ll 0.35$$
$$x = 0.015; \quad -\log x = 1.81$$

(25) Which one of the following is the weakest acid?

- a) HF ( $K_a = 6.8 \times 10^{-4}$ )
- b) HClO ( $K_a = 3.0 \times 10^{-8}$ )
- c) HNO<sub>2</sub> ( $K_a = 4.5 \times 10^{-4}$ )
- d) HCN ( $K_a = 4.9 \times 10^{-10}$ )
- e) Acetic acid ( $K_a = 1.8 \times 10^{-5}$ )

# PERIODIC TABLE OF THE ELEMENTS

Main groups																																																																																	
1A <sup>a</sup>																																																																																	
1																																																																																	
2A																																																																																	
2																																																																																	
Transition metals																																																																																	
3B 4B 5B 6B 7B 8B 9B 10B 11B 12B																																																																																	
3A 4A 5A 6A 7A																																																																																	
13 14 15 16 17																																																																																	
8A																																																																																	
18																																																																																	
3 Li 6.941	4 Be 9.01218	11 Na 22.98977	12 Mg 24.305	19 K 39.0983	20 Ca 40.078	37 Rb 85.4678	55 Cs 132.9054	87 Fr (223)	21 Sc 44.9559	22 Ti 47.88	39 Y 88.9059	72 Hf 178.49	104 Rf (261)	23 V 50.9415	24 Cr 51.9961	41 Nb 92.9064	73 Ta 180.9479	105 Db (262)	25 Mn 54.9380	26 Fe 55.847	43 Tc (98)	75 Re 186.207	107 Ts (262)	27 Co 58.9332	28 Ni 58.6934	45 Rh 102.9055	77 Ir 192.22	109 Nh (269)	29 Cu 63.546	30 Zn 65.39	47 Ag 107.8682	79 Au 196.9665	111 Nh (272)	31 Ga 69.723	32 Ge 72.61	49 In 114.82	81 Tl 204.3833	51 Sb 121.757	83 Bi 208.9804	33 As 74.9216	34 Se 78.96	52 Te 127.60	84 Po (209)	35 Br 79.904	36 Kr 83.90	53 I 126.9045	85 At (210)	38 Sr 87.62	38 Sr 87.62	56 Ba 137.327	57 *La 138.9055	88 Ra 226.0254	89 *Ac 227.0278	58 Ce 140.115	59 Pr 140.9077	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.965	64 Gd 157.25	65 Tb 158.9254	66 Dy 162.50	67 Ho 164.9303	68 Er 167.26	69 Tm 168.9342	70 Yb 173.04	71 Lu 174.967	90 Th 232.0381	91 Pa 231.0359	92 U 238.0289	93 Np 237.048	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

<sup>a</sup>The larger labels are common American usage. The smaller labels are those recommended by the International Union of Pure and Applied Chemistry. The names and symbols for elements 104 and above are still under debate.