

CHEM 311 (141)

Final Exam

3 HOURS

Thursday, January 8, 2015, 7:00 PM

Building 10

Test Code (001)

(25 Questions)

Dr. Oweimreen	Section 1
Dr. Mazen Khaled	Section 2
Dr. Mohamed Morsy	Section 3
Dr. Foerner	Section 4

Physical constants, conversion factors, and useful equations

Physical Constants

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$= 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$$

$$= 0.08314 \text{ L bar K}^{-1} \text{ mol}^{-1}$$

$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$k_B = 1.381 \times 10^{-23} \text{ J K}^{-1}$$

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$F = 96,485 \text{ C mol}^{-1}$$

$$c = 2.998 \times 10^8 \text{ m s}^{-1}$$

$$g = 9.81 \text{ m s}^{-2}$$

$$e = 1.6022 \times 10^{-19} \text{ C}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$$

$$B = 0.51 \text{ mol}^{-1/2} \text{ dm}^{3/2} \text{ (in H}_2\text{O, 25}^\circ\text{C)}$$

Other Units

$$1 \text{ dm}^3 = 1 \text{ L}$$

$$1 \text{ dm}^3 = 1000 \text{ cm}^3$$

$$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

$$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa}$$

$$1 \text{ atm} = 760 \text{ mmHg}$$

$$1 \text{ Torr} = 1 \text{ mmHg}$$

$$1 \text{ Torr} = 133.322 \text{ Pa}$$

$$1 \text{ bar} = 10^5 \text{ Pa}$$

$$E = h\nu$$

$$c = \nu\lambda$$

$$PV = nRT$$

$$(RT)/F = 25.6926 \text{ mV at } 25^\circ\text{C}$$

$$\ln(x)/\log_{10}(x) = 2.30259 \text{ for all } x$$

$$\ln(1 - \theta) = -\theta$$

$$\text{if } \theta \ll 1$$

Quadratic equation:

$$a x^2 + b x + c = 0$$

solutions:

$$x_{1,2} = (1/2a)[-b \pm (b^2 - 4ac)^{1/2}]$$

$$RT/F = 25.70 \text{ mV (at } 25^\circ\text{C for ln)}$$

$$= 59.16 \text{ mV (at } 25^\circ\text{C for log}_{10})$$

Michaelis - Menten equation:

$$(1/R_0) = (1/R_{\max}) + (K_m/R_{\max}) \times (1/[S]_0)$$

Lindemann mechanism:

$$k_{\text{uni}} = k_1 k_2 [M] (k_{-1}[M] + k_2)^{-1}$$

Langmuir isotherm:

$$\theta = KP / (1 + KP)$$

$$1/R_0 = 1/R_{\max} + (K_m/R_{\max}) (1/[S]_0)$$

Sequential reactions:

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

$$[B] = (k_1 / (k_2 - k_1)) f(t) [A]_0$$

$$f(t) = \exp(-k_1 t) - \exp(-k_2 t)$$

Important Equations

$$\Lambda = \frac{\kappa}{c}, \quad \alpha = \frac{\Lambda}{\Lambda_0} \quad \text{and} \quad I = \frac{I}{2} \sum_i c_i z_i^2$$

$$\log_{10} \gamma_i = -z_i^2 B \sqrt{I} \quad \text{and} \quad \log_{10} \gamma_{\pm} = -z_{\pm} |z_{\pm}| B \sqrt{I}$$

$$\Lambda_m = \Lambda_m^\circ - K (c/c_0)^{1/2} \text{ (strong)}$$

$$1/\Lambda_m = 1/\Lambda_m^\circ + c \Lambda_m / [(\Lambda_m^\circ)^2 K_a] \text{ (weak)}$$

$$\Delta G^\circ_{\text{solution}} = (1/\epsilon_r - 1) z^2 e^2 N_A / (8\pi \epsilon_0 r)$$

$$E = E^\circ - \frac{RT}{zF} \ln \left(\frac{[Y]^y [Z]^z}{[A]^a [B]^b} \right)^u$$

$$\Delta G = -nFE \quad \text{and thus} \quad \Delta G^\circ = -nFE^\circ$$

$$\Delta S = nF(dE/dt)_p$$

$$a_{\pm}^{m+n} = a_+^m a_-^n \text{ for } A_m B_n$$

$$\kappa = [2e^2 N_A \times (1000 \text{ L m}^{-3}) / (\epsilon_0 k_B T)]^{1/2} \times [\rho_{\text{solvent}} / \epsilon_r]^{1/2}$$

$$E^\circ_{\text{AgCl/Ag}} = +0.222 \text{ V}$$

$$k = A e^{-E_a / RT}$$

$$k = \frac{k_B T}{h} e^{-\Delta^\ddagger G^\circ / RT}$$

$$E_a = \Delta^\ddagger H^\circ - P \Delta^\ddagger V^\circ + RT \text{ (sol)}$$

$$= \Delta^\ddagger H^\circ - \Sigma \nu RT + RT \text{ (gas)}$$

$$\Delta G^\ddagger = \Delta H^\ddagger - T \Delta S^\ddagger$$

$$t_{1/2} = (\ln 2) / k \text{ (1st order)}$$

fluorescence lifetime $t_f = (k_f + k_q[Q])^{-1}$

$$R_0 = k_2 [S]_0 [E]_0 / ([S]_0 + K_m),$$

$$K_m = (k_{-1} + k_2) / k_1$$

$$k_2 [E]_0 = R_{\max} = V$$

$$D = (1/3) v_{\text{ave}} \lambda$$

$$\kappa = (1/3) (C_{V,m} / N_A) v_{\text{ave}} N_p \lambda$$

$$PV = nRT = (N/N_A) RT,$$

$$(C_{V,m} / N_A) = (3/2) k_B$$

$$\eta = (1/3) v_{\text{ave}} N_p \lambda m$$

$$f = 6\pi \eta r = k_B T / D$$

$$v_{\text{ave}} = (8RT / (\pi M))^{1/2}$$

$$N_p \lambda = 1 / ((\sqrt{2}) \sigma),$$

$$\lambda = RT / (P N_A (\sqrt{2}) \sigma)$$

$$N_p = (N/V) = P N_A / (RT)$$

$$\sigma = \pi d^2$$

$$x_{\text{rms}} = \sqrt{(2Dt)} \quad (1\text{-Dimension})$$

$$r_{\text{rms}} = \sqrt{(6Dt)} \quad (3\text{-Dimension})$$

Poiseuille equation: $(\Delta V / \Delta t) = (\pi r^4 / (8\eta)) \Delta P / \Delta L$

Stokes-Einstein equation: $D = k_B T / (6\pi \eta r)$

if $r(\text{particle}) \gg r(\text{solvent molecule})$

Ostwald viscosimeter: $\eta = A \rho t$,

Capillary rise: $h = 2\gamma / (\rho g r)$

Note:

Quantum yield/efficiency = Φ = moles of product formed / moles of photons absorbed

1. For the protein myoglobin in water at 20 °C, the sedimentation coefficient is $s_{\text{sed}} = 2.04 \times 10^{-13}$ s, the diffusion coefficient is $D = 1.13 \times 10^{-10}$ m² s⁻¹, and the specific volume is 0.740 cm³ g⁻¹. The density of water is 0.998 g cm⁻³ and its viscosity is 1.002 cP at the same temperature. Estimate the radius of myoglobin, assuming it to be spherical.
- A) 1.897 nm
 B) 9.114 nm
 C) 5.232 nm
 D) 4.115 nm
 E) 3.150 nm
2. The adsorption of an organic compound on an adsorbent measured at 5 °C and different pressures followed the Langmuir type of isotherm and a fit of $1/V_{\text{ads}}$ versus $1/P$ gave,
- $$1/V_{\text{ads}} = 2.662 \text{ (torr/mL)} (1/P) + 0.203 \text{ (1/mL)}$$
- where V_{ads} is the volume of the adsorbed organic compound in mL and P is its pressure in torr. The fractional coverage of charcoal at a pressure of 100 torr is,
- A) 0.203
 B) 0.376
 C) 0.884
 D) 0.430
 E) 0.612
3. The viscosity of ethylene at 25 °C and 101.325 kPa is 9.33×10^{-6} kg m⁻¹ s⁻¹. Estimate the molecular diameter of the ethylene molecule ($M_{\text{C}} = 12.01$ g/mol, $M_{\text{H}} = 1.008$ g/mol).
- A) 2.22 nm
 B) 0.67 nm
 C) 0.14 nm
 D) 1.19 nm
 E) 0.42 nm

4. Consider the photochemical decomposition:



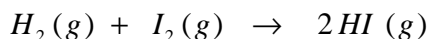
With light at $\lambda = 253.7$ nm, absorption of 3070 J of energy decomposed

1.30×10^{-2} mol HI. The quantum yield of this reaction is:

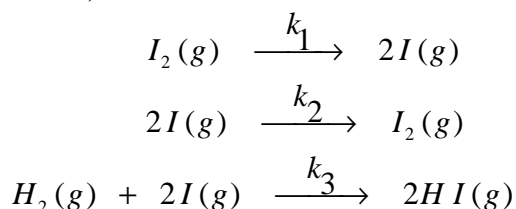
- A) 5
 B) 2
 C) 0.5
 D) 1
 E) 10^6

5. Liquid A has half the surface tension and twice the density of liquid B, at 25 °C. If the capillary rise is 0.01 m for liquid A, then in the same capillary, the capillary rise for liquid B will be (assume complete wetting)
- 0.01 m
 - 0.05 m
 - 0.02 m
 - 0.03 m
 - 0.04 m
6. Krypton (Kr) and Helium (He) are monatomic gases, and thus $C_{V,m} = 3/2 R$ for each. Given that $\sigma_{Kr} = 0.52 \text{ nm}^2$ and $\sigma_{He} = 0.28 \text{ nm}^2$ and that the molar mass of Kr is larger than that of He which one of the following is definitely correct?
- Since $\lambda_{Kr} < \lambda_{He}$ and $v_{ave,Kr} < v_{ave,He}$ it follows that $\kappa_{Kr} < \kappa_{He}$
 - Since $\lambda_{Kr} > \lambda_{He}$ and $v_{ave,Kr} > v_{ave,He}$ it follows that $\kappa_{Kr} < \kappa_{He}$
 - Actually $\kappa_{Kr} > \kappa_{He}$
 - Since $\lambda_{Kr} > \lambda_{He}$ and $v_{ave,Kr} < v_{ave,He}$ it follows that $\kappa_{Kr} < \kappa_{He}$
 - Since $\lambda_{Kr} < \lambda_{He}$ and $v_{ave,Kr} > v_{ave,He}$ it follows that $\kappa_{Kr} < \kappa_{He}$
7. The densities of acetone and water at 20 °C are 0.972 g cm^{-3} and 0.9982 g cm^{-3} , respectively. The viscosity of water is $1.002 \times 10^{-3} \text{ Pa s}$ at 20 °C. If at 20 °C water requires 120.5 s to run between the marks on a viscometer and acetone requires 40.5 s, what is the viscosity of acetone?
- $1.03 \times 10^{-3} \text{ Pa s}$
 - $2.90 \times 10^{-3} \text{ Pa s}$
 - $3.28 \times 10^{-4} \text{ Pa s}$
 - $6.56 \times 10^{-4} \text{ Pa s}$
 - $3.06 \times 10^{-3} \text{ Pa s}$

8. The reaction,



takes place in the presence of light. The mechanism which gives a rate law that agrees with experiment is,



The rate law is:

- A) $Rate = \frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [HI]}$
B) $Rate = \frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [I_2]}$
C) $Rate = \frac{k_1 k_3 [H_2]}{k_2 + k_3 [HI]}$
D) $Rate = \frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [H_2]}$
E) $Rate = \frac{k_1 k_3 [I_2]}{k_2 + k_3 [H_2]}$

9. The solubility product of K_2SO_4 is (γ_{\pm} is the mean activity coefficient):

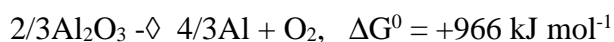
- A) $4s^2\gamma_{\pm}^3$
B) $4s^5\gamma_{\pm}^3$
C) $4s^3\gamma_{\pm}^2$
D) $4s^3\gamma_{\pm}^3$
E) $4s^3\gamma_{\pm}^5$

10. The Galvanic cell $Cu(s) | Cu^{2+}(aq) || Ag^+(aq) | Ag(s)$ is based on the following cell reaction: $2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$. Note that $T = 298\text{ K}$ and the standard electrode potentials are $E^0(Cu^{2+}, Cu) = 0.34\text{ V}$ and $E^0(Ag^+, Ag) = 0.80\text{ V}$. Which of the following statements are correct?

- (i) The silver electrode is the cathode and the copper electrode is the anode.
(ii) Two moles of electrons flow through the external circuit from anode to cathode when the cell operates.
(iii) The standard cell potential is 0.46 V .
(iv) The change in Gibbs energy for the cell reaction is $-88,766\text{ J mol}^{-1}$ in the standard state.
- A) All statements are not correct.
B) (iii) and (iv) are correct.
C) (i) and (ii) are correct.
D) (i) is correct.
E) All statements are correct.

11. The flux of a property (J) is related to the gradient of the transported quantity (grad) as (α is the transport coefficient)
- A) J proportional to $-1/\text{grad}$
 - B) J proportional to α^2
 - C) J proportional to $-\text{grad}$
 - D) J proportional to $1/\alpha$
 - E) J proportional to $1/\text{grad}$
12. The Arrhenius parameters for the unimolecular isomerization of methylcyanide,
- $$\text{CH}_3\text{NC}(g) \rightarrow \text{CH}_3\text{CN}(g)$$
- are an activation energy of 272 kJ/mol and a preexponential factor of $2.5 \times 10^{16} \text{ s}^{-1}$. Which of the following choices is completely correct for the ΔH^\ddagger (in kJ/mol) and ΔS^\ddagger (in J/(K mol)) values (from left to right) at 227 °C.
- A) 268, 56.4
 - B) 270, 63.0
 - C) 264, 63.0
 - D) 272, 435
 - E) 276, 240
13. What is the diffusion coefficient of xenon (Xe) at 298 K and a pressure of 2.00 atm, given the collisional cross section of Xe as $\sigma = 5.8 \times 10^{-19} \text{ m}^2$ and $M_{\text{Xe}} = 131.29 \text{ g/mol}$?
- A) $5.72 \times 10^{-8} \text{ m}^2/\text{s}$
 - B) $1.81 \times 10^{-6} \text{ m}^2/\text{s}$
 - C) $5.43 \times 10^{-6} \text{ m}^2/\text{s}$
 - D) $0.18 \text{ m}^2/\text{s}$
 - E) $1.72 \times 10^{-7} \text{ m}^2/\text{s}$
14. Which of the following statements is not correct?
- A) The viscosities of gases decrease as temperature increases.
 - B) The viscosities of liquids obey a law of the Arrhenius type.
 - C) For gases, viscosity is proportional to $T^{1/2}$, T being the temperature in Kelvin.
 - D) The viscosities of gases increase as temperature increases.
 - E) The viscosities of liquids increase as temperature decreases.
15. Given that the mean activity coefficient, γ_{\pm} , in a 0.100 mol kg^{-1} $\text{MgBr}_2(\text{aq})$ solution is 0.524 at 25°C. Determine the percentage difference from the value predicted by the Debye-Hückel limiting law?
- A) 21%
 - B) 11%
 - C) 47%
 - D) 17%
 - E) 15%

16. The following reaction corresponds to electroextraction of aluminum from aluminum ore:



The minimum potential required to drive this reaction at 500°C is:

- A) 1.2V
B) 5.0V
C) 4.5V
D) 2.5V
E) 3.0V
17. Thermopane windows filled with krypton (Kr, $M_{\text{Kr}} = 83.80 \text{ g/mol}$) provide a ten times better heat insulation than normal windows filled with argon (Ar, $M_{\text{Ar}} = 39.95 \text{ g/mol}$), advertisements claim. What is the ratio of the thermal conductivity of Kr ($\sigma = 0.52 \text{ nm}^2$) to that of Ar ($\sigma = 0.36 \text{ nm}^2$) and does it fulfill the advertisement claim of a ten times better heat insulation?
- A) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, does not fulfill the advertisement
B) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 3.03$, fulfills the advertisement
C) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 2.09$, does not fulfill the advertisement
D) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.33$, does not fulfill the advertisement
E) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, fulfills the advertisement
18. The rate constant for the second order reaction between iodomethane, CH_3I , and ethoxy anions, $\text{C}_2\text{H}_5\text{O}^-$, in ethanol solution is $9.86 \times 10^{-5} \text{ mol dm}^{-3}\text{s}^{-1}$ at 25 °C and $6.17 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$ at 65 °C. Calculate the activation energy in kJ mol^{-1} units.
- A) 10.4
B) 116
C) 300
D) 40.0
E) 86.7
19. At the same temperature and pressure, $D_{\text{Xe}} = 4.4 D_{\text{Rn}}$. What is the ratio, $\sigma_{\text{Rn}}/\sigma_{\text{Xe}}$, of their collisional cross sections if $M_{\text{Xe}} = 131.29 \text{ g/mol}$ and $M_{\text{Rn}} = 222 \text{ g/mol}$.
- A) 5.72
B) 2.60
C) 3.38
D) 0.30
E) 0.77

20. Given the following Galvanic cell $\text{Zn(s)}|\text{Zn}^{2+}(\text{aq})||\text{Sn}^{4+}(\text{aq}),\text{Sn}^{2+}(\text{aq})|\text{Pt(s)}$. If the standard potential $E^0(\text{Zn}^{2+},\text{Zn}) = -0.76 \text{ V}$ and the standard cell potential $E^0_{\text{cell}} = 0.91 \text{ V}$, then the standard potential of the $\text{Sn}^{4+}/\text{Sn}^{2+}$ redox couple is:
- A) 0.15 V
 - B) 1.67 V
 - C) -0.15 V
 - D) 150 V
 - E) -1.67 V
21. What is the ratio of the root mean square displacement in three dimensions (r_{rms}) to that in one dimension (x_{rms}) for a particle with $D = 3.41 \times 10^{-5} \text{ m}^2/\text{s}$ in 900 s in case of r_{rms} and in 1800s in case of x_{rms} ?
- A) $(1/6)^{1/2}$
 - B) $(3/2)^{1/2}$
 - C) $3/2$
 - D) $(6)^{1/2}$
 - E) $(2/3)^{1/2}$
22. The thermal conductivity of Helium, He, at 300 K and 1.00 atm is $0.0612 \text{ J}/(\text{K m s})$. What is the mean free path length of He, assuming it to behave like an ideal gas ($M_{\text{He}} = 4.003 \text{ g/mol}$)?
- A) 288 nm
 - B) $9.11 \mu\text{m}$
 - C) 2.9 mm
 - D) 96 nm
 - E) 3.0μ
23. If the diffusion coefficient for insulin is $8.2 \times 10^{-11} \text{ m}^2 \text{ s}^{-1}$ at $20 \text{ }^\circ\text{C}$, estimate the mean time required for an insulin molecule to diffuse through a distance equal to the diameter of a typical living cell ($\sim 10 \mu\text{m}$).
- A) 2.1 s
 - B) 0.17 s
 - C) 3.2 s
 - D) 1.1 s
 - E) 0.61 s

24. Water is transported upward in trees through channels in the trunk called xylem. Although the diameter of the xylem channels varies from species to species, a typical value is 2.0×10^{-7} m. If the water surface tension and density are 70.41×10^{-3} N m⁻¹ and 997 kg m⁻³, what will be the maximum transport height of the water to the top in the redwood tree?
- A) 144 m
 - B) 45.9 m
 - C) 95.0 m
 - D) 21.0 m
 - E) 214 m
25. The conductivity of a 0.0312 M solution of a weak base is 1.53×10^{-4} S cm⁻¹. If the sum of the limiting ionic conductance for BH⁺ and OH⁻ is 237.0 S cm² mol⁻¹, what is the value of the base dissociation constant K_b ?
- A) 2.12×10^{-6}
 - B) 1.51×10^{-4}
 - C) 1.36×10^{-5}
 - D) 3.21×10^{-4}
 - E) 2.11×10^{-3}

Answer Key

1. A
2. C
3. E
4. B
5. E
6. A
7. C
8. D
9. D
10. E
11. C
12. A
13. B
14. A
15. C
16. D
17. A
18. E
19. C
20. A
21. B
22. A
23. E
24. A
25. C

CHEM 311 (141)

Final Exam

3 HOURS

Thursday, January 8, 2015, 7:00 PM

Building 10

Test Code (002)

(25 Questions)

Dr. Oweimreen	Section 1
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solutions:

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Lindemann mechanism:

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Langmuir isotherm:

$$\theta = KP / (1 + KP)$$

$$1/R_0 = 1/R_{\max} + (K_m/R_{\max}) (1/[S]_0)$$

Sequential reactions:

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

$$[B] = (k_1 / (k_2 - k_1)) f(t) [A]_0$$

$$f(t) = \exp(-k_1 t) - \exp(-k_2 t)$$

Important Equations

$$\Lambda = \frac{\kappa}{c}, \alpha = \frac{\Lambda}{\Lambda_0} \text{ and } I = \frac{I}{2} \sum_i c_i z_i^2$$

$$\log_{10} \gamma_i = -z_i^2 B \sqrt{I} \text{ and } \log_{10} \gamma_{\pm} = -z_{\pm} / z_{\pm} / B \sqrt{I}$$

$$\Lambda_m = \Lambda_m^\circ - K (c/c_0)^{1/2} \text{ (strong)}$$

$$1/\Lambda_m = 1/\Lambda_m^\circ + c \Lambda_m / [(\Lambda_m^\circ)^2 K_a] \text{ (weak)}$$

$$\Delta G^\circ_{\text{solution}} = (1/\epsilon_r - 1) z^2 e^2 N_A / (8\pi \epsilon_0 r)$$

$$E = E^\circ - \frac{RT}{zF} \ln \left(\frac{[Y]^y [Z]^z}{[A]^a [B]^b} \right)^u$$

$$\Delta G = -nFE \text{ and thus } \Delta G^\circ = -nFE^\circ$$

$$\Delta S = nF(dE/dt)_p$$

$$a_{\pm}^{m+n} = a_+^m a_-^n \text{ for } A_m B_n$$

$$\kappa = [2e^2 N_A \times (1000 \text{ L m}^{-3}) / (\epsilon_0 k_B T)]^{1/2} \times [\rho_{\text{solvent}} / \epsilon_r]^{1/2}$$

$$E^\circ_{\text{AgCl/Ag}} = +0.222 \text{ V}$$

$$k = A e^{-E_a / RT}$$

$$k = \frac{k_B T}{h} e^{-\Delta^\ddagger G^\circ / RT}$$

$$E_a = \Delta^\ddagger H^\circ - P \Delta^\ddagger V^\circ + RT \text{ (sol)}$$

$$= \Delta^\ddagger H^\circ - \Sigma \nu RT + RT \text{ (gas)}$$

$$\Delta G^\ddagger = \Delta H^\ddagger - T \Delta S^\ddagger$$

$$t_{1/2} = (\ln 2) / k \text{ (1}^\text{st} \text{ order)}$$

fluorescence lifetime $t_f = (k_f + k_q[Q])^{-1}$

$$R_0 = k_2 [S]_0 [E]_0 / ([S]_0 + K_m),$$

$$K_m = (k_{-1} + k_2) / k_1$$

$$k_2 [E]_0 = R_{\max} = V$$

$$D = (1/3) v_{\text{ave}} \lambda$$

$$\kappa = (1/3) (C_{V,m} / N_A) v_{\text{ave}} N_p \lambda$$

$$PV = nRT = (N/N_A) RT,$$

$$(C_{V,m} / N_A) = (3/2) k_B$$

$$\eta = (1/3) v_{\text{ave}} N_p \lambda m$$

$$f = 6\pi \eta r = k_B T / D$$

$$v_{\text{ave}} = (8RT / (\pi M))^{1/2}$$

$$N_p \lambda = 1 / ((\sqrt{2}) \sigma),$$

$$\lambda = RT / (P N_A (\sqrt{2}) \sigma)$$

$$N_p = (N/V) = P N_A / (RT)$$

$$\sigma = \pi d^2$$

$$x_{\text{rms}} = \sqrt{(2Dt)} \quad (1\text{-Dimension})$$

$$r_{\text{rms}} = \sqrt{(6Dt)} \quad (3\text{-Dimension})$$

Poiseuille equation: $(\Delta V / \Delta t) = (\pi r^4 / (8\eta)) \Delta P / \Delta L$

Stokes-Einstein equation: $D = k_B T / (6\pi \eta r)$

if $r(\text{particle}) \gg r(\text{solvent molecule})$

Ostwald viscosimeter: $\eta = A \rho t$,

Capillary rise: $h = 2\gamma / (\rho g r)$

Note:

Quantum yield/efficiency = Φ = moles of product formed / moles of photons absorbed

- At the same temperature and pressure, $D_{Xe} = 4.4 D_{Rn}$. What is the ratio, σ_{Rn}/σ_{Xe} , of their collisional cross sections if $M_{Xe} = 131.29$ g/mol and $M_{Rn} = 222$ g/mol.
 - 2.60
 - 0.30
 - 5.72
 - 0.77
 - 3.38

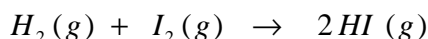
- Given the following Galvanic cell $Zn(s)|Zn^{2+}(aq)||Sn^{4+}(aq),Sn^{2+}(aq)|Pt(s)$. If the standard potential $E^0(Zn^{2+},Zn) = -0.76$ V and the standard cell potential $E^0_{cell} = 0.91$ V, then the standard potential of the Sn^{4+}/Sn^{2+} redox couple is:
 - 1.67 V
 - 0.15 V
 - 1.67 V
 - 0.15 V
 - 150 V

- The Galvanic cell $Cu(s)|Cu^{2+}(aq)||Ag^+(aq)|Ag(s)$ is based on the following cell reaction: $2Ag^+(aq)+Cu(s)\rightarrow 2Ag(s)+Cu^{2+}(aq)$. Note that $T = 298$ K and the standard electrode potentials are $E^0(Cu^{2+},Cu) = 0.34$ V and $E^0(Ag^+,Ag) = 0.80$ V. Which of the following statements are correct?
 - The silver electrode is the cathode and the copper electrode is the anode.
 - Two moles of electrons flow through the external circuit from anode to cathode when the cell operates.
 - The standard cell potential is 0.46 V.
 - The change in Gibbs energy for the cell reaction is $-88,766$ J mol⁻¹ in the standard state.
 - (i) is correct.
 - (i) and (ii) are correct.
 - All statements are not correct.
 - All statements are correct.
 - (iii) and (iv) are correct.

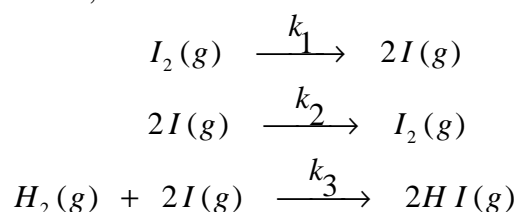
- The densities of acetone and water at 20 °C are 0.972 g cm⁻³ and 0.9982 g cm⁻³, respectively. The viscosity of water is 1.002×10^{-3} Pa s at 20 °C. If at 20 °C water requires 120.5 s to run between the marks on a viscometer and acetone requires 40.5 s, what is the viscosity of acetone?
 - 6.56×10^{-4} Pa s
 - 3.28×10^{-4} Pa s
 - 3.06×10^{-3} Pa s
 - 2.90×10^{-3} Pa s
 - 1.03×10^{-3} Pa s

5. If the diffusion coefficient for insulin is $8.2 \times 10^{-11} \text{ m}^2 \text{ s}^{-1}$ at 20°C , estimate the mean time required for an insulin molecule to diffuse through a distance equal to the diameter of a typical living cell ($\sim 10 \mu\text{m}$).
- A) 0.17 s
 B) 1.1 s
 C) 0.61 s
 D) 3.2 s
 E) 2.1 s

6. The reaction,



takes place in the presence of light. The mechanism which gives a rate law that agrees with experiment is,



The rate law is:

- A) $\text{Rate} = \frac{k_1 k_3 [\text{H}_2][\text{I}_2]}{k_2 + k_3 [\text{I}_2]}$
 B) $\text{Rate} = \frac{k_1 k_3 [\text{H}_2][\text{I}_2]}{k_2 + k_3 [\text{H}_2]}$
 C) $\text{Rate} = \frac{k_1 k_3 [\text{H}_2][\text{I}_2]}{k_2 + k_3 [\text{HI}]}$
 D) $\text{Rate} = \frac{k_1 k_3 [\text{I}_2]}{k_2 + k_3 [\text{H}_2]}$
 E) $\text{Rate} = \frac{k_1 k_3 [\text{H}_2]}{k_2 + k_3 [\text{HI}]}$
7. The adsorption of an organic compound on an adsorbent measured at 5°C and different pressures followed the Langmuir type of isotherm and a fit of $1/V_{ads}$ versus $1/P$ gave,

$$1/V_{ads} = 2.662 \text{ (torr/mL)} (1/P) + 0.203 \text{ (1/mL)}$$

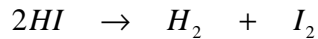
where V_{ads} is the volume of the adsorbed organic compound in mL and P is its pressure in torr. The fractional coverage of charcoal at a pressure of 100 torr is,

- A) 0.376
 B) 0.612
 C) 0.430
 D) 0.203
 E) 0.884

8. Water is transported upward in trees through channels in the trunk called xylem. Although the diameter of the xylem channels varies from species to species, a typical value is 2.0×10^{-7} m. If the water surface tension and density are 70.41×10^{-3} N m⁻¹ and 997 kg m⁻³, what will be the maximum transport height of the water to the top in the redwood tree?
- A) 45.9 m
 B) 21.0 m
 C) 214 m
 D) 95.0 m
 E) 144 m
9. Given that the mean activity coefficient, γ_{\pm} , in a 0.100 mol kg⁻¹ MgBr₂(aq) solution is 0.524 at 25°C . Determine the percentage difference from the value predicted by the Debye-Hückel limiting law?
- A) 11%
 B) 15%
 C) 17%
 D) 21%
 E) 47%
10. The following reaction corresponds to eletroextraction of aluminum from aluminum ore:
- $$2/3\text{Al}_2\text{O}_3 \rightarrow 4/3\text{Al} + \text{O}_2, \quad \Delta G^0 = +966 \text{ kJ mol}^{-1}$$
- The minimum potential required to drive this reaction at 500°C is:
- A) 4.5V
 B) 2.5V
 C) 5.0V
 D) 3.0V
 E) 1.2V
11. For the protein myoglobin in water at 20°C , the sedimentation coefficient is $s_{\text{sed}} = 2.04 \times 10^{-13}$ s, the diffusion coefficient is $D = 1.13 \times 10^{-10}$ m² s⁻¹, and the specific volume is 0.740 cm³ g⁻¹. The density of water is 0.998 g cm⁻³ and its viscosity is 1.002 cP at the same temperature. Estimate the radius of myoglobin, assuming it to be spherical.
- A) 3.150 nm
 B) 4.115 nm
 C) 1.897 nm
 D) 5.232 nm
 E) 9.114 nm

12. What is the diffusion coefficient of xenon (Xe) at 298 K and a pressure of 2.00 atm, given the collisional cross section of Xe as $\sigma = 5.8 \times 10^{-19} \text{ m}^2$ and $M_{\text{Xe}} = 131.29 \text{ g/mol}$?
- A) $0.18 \text{ m}^2/\text{s}$
 - B) $1.72 \times 10^{-7} \text{ m}^2/\text{s}$
 - C) $1.81 \times 10^{-6} \text{ m}^2/\text{s}$
 - D) $5.43 \times 10^{-6} \text{ m}^2/\text{s}$
 - E) $5.72 \times 10^{-8} \text{ m}^2/\text{s}$
13. Which of the following statements is not correct?
- A) For gases, viscosity is proportional to $T^{1/2}$, T being the temperature in Kelvin.
 - B) The viscosities of gases decrease as temperature increases.
 - C) The viscosities of gases increase as temperature increases.
 - D) The viscosities of liquids increase as temperature decreases.
 - E) The viscosities of liquids obey a law of the Arrhenius type.
14. What is the ratio of the root mean square displacement in three dimensions (r_{rms}) to that in one dimension (x_{rms}) for a particle with $D = 3.41 \times 10^{-5} \text{ m}^2/\text{s}$ in 900 s in case of r_{rms} and in 1800s in case of x_{rms} ?
- A) $(6)^{1/2}$
 - B) $(2/3)^{1/2}$
 - C) $(1/6)^{1/2}$
 - D) $(3/2)^{1/2}$
 - E) $3/2$
15. The conductivity of a 0.0312 M solution of a weak base is $1.53 \times 10^{-4} \text{ S cm}^{-1}$. If the sum of the limiting ionic conductance for BH^+ and OH^- is $237.0 \text{ S cm}^2 \text{ mol}^{-1}$, what is the value of the base dissociation constant K_b ?
- A) 1.51×10^{-4}
 - B) 1.36×10^{-5}
 - C) 2.11×10^{-3}
 - D) 2.12×10^{-6}
 - E) 3.21×10^{-4}
16. Liquid A has half the surface tension and twice the density of liquid B, at 25 °C. If the capillary rise is 0.01 m for liquid A, then in the same capillary, the capillary rise for liquid B will be (assume complete wetting)
- A) 0.03 m
 - B) 0.04 m
 - C) 0.05 m
 - D) 0.02 m
 - E) 0.01 m

17. Consider the photochemical decomposition:



With light at $\lambda = 253.7 \text{ nm}$, absorption of 3070 J of energy decomposed $1.30 \times 10^{-2} \text{ mol HI}$. The quantum yield of this reaction is:

- A) 2
B) 1
C) 5
D) 10^6
E) 0.5
18. The thermal conductivity of Helium, He, at 300 K and 1.00 atm is 0.0612 J/(K m s). What is the mean free path length of He, assuming it to behave like an ideal gas ($M_{\text{He}} = 4.003 \text{ g/mol}$)?
A) 2.9 mm
B) 288 nm
C) 96 nm
D) 3.0 μ
E) 9.11 μm
19. Thermopane windows filled with krypton (Kr, $M_{\text{Kr}} = 83.80 \text{ g/mol}$) provide a ten times better heat insulation than normal windows filled with argon (Ar, $M_{\text{Ar}} = 39.95 \text{ g/mol}$), advertisements claim. What is the ratio of the thermal conductivity of Kr ($\sigma = 0.52 \text{ nm}^2$) to that of Ar ($\sigma = 0.36 \text{ nm}^2$) and does it fulfill the advertisement claim of a ten times better heat insulation?
A) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 2.09$, does not fulfill the advertisement
B) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.33$, does not fulfill the advertisement
C) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, fulfills the advertisement
D) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, does not fulfill the advertisement
E) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 3.03$, fulfills the advertisement
20. The solubility product of K_2SO_4 is (γ_{\pm} is the mean activity coefficient):
A) $4s^3\gamma_{\pm}^2$
B) $4s^3\gamma_{\pm}^5$
C) $4s^5\gamma_{\pm}^3$
D) $4s^2\gamma_{\pm}^3$
E) $4s^3\gamma_{\pm}^3$

21. The rate constant for the second order reaction between iodomethane, CH_3I , and ethoxy anions, $\text{C}_2\text{H}_5\text{O}^-$, in ethanol solution is $9.86 \times 10^{-5} \text{ mol dm}^{-3}\text{s}^{-1}$ at 25°C and $6.17 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$ at 65°C . Calculate the activation energy in kJ mol^{-1} units.
- A) 40.0
 B) 10.4
 C) 86.7
 D) 300
 E) 116
22. The flux of a property (J) is related to the gradient of the transported quantity (grad) as (α is the transport coefficient)
- A) J proportional to $1/\text{grad}$
 B) J proportional to $-1/\text{grad}$
 C) J proportional to $1/\alpha$
 D) J proportional to α^2
 E) J proportional to $-\text{grad}$
23. The Arrhenius parameters for the unimolecular isomerization of methylcyanide,
- $$\text{CH}_3\text{NC}(g) \rightarrow \text{CH}_3\text{CN}(g)$$
- are an activation energy of 272 kJ/mol and a preexponential factor of $2.5 \times 10^{16} \text{ s}^{-1}$. Which of the following choices is completely correct for the ΔH^\ddagger (in kJ/mol) and ΔS^\ddagger (in J/(K mol)) values (from left to right) at 227°C .
- A) 272, 435
 B) 268, 56.4
 C) 270, 63.0
 D) 276, 240
 E) 264, 63.0
24. The viscosity of ethylene at 25°C and 101.325 kPa is $9.33 \times 10^{-6} \text{ kg m}^{-1} \text{ s}^{-1}$. Estimate the molecular diameter of the ethylene molecule ($M_C = 12.01 \text{ g/mol}$, $M_H = 1.008 \text{ g/mol}$).
- A) 1.19 nm
 B) 0.42 nm
 C) 2.22 nm
 D) 0.67 nm
 E) 0.14 nm

25. Krypton (Kr) and Helium (He) are monatomic gases, and thus $C_{V,m} = 3/2 R$ for each. Given that $\sigma_{\text{Kr}} = 0.52 \text{ nm}^2$ and $\sigma_{\text{He}} = 0.28 \text{ nm}^2$ and that the molar mass of Kr is larger than that of He which one of the following is definitely correct?
- A) Actually $\kappa_{\text{Kr}} > \kappa_{\text{He}}$
 - B) Since $\lambda_{\text{Kr}} > \lambda_{\text{He}}$ and $v_{\text{ave,Kr}} < v_{\text{ave,He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$
 - C) Since $\lambda_{\text{Kr}} > \lambda_{\text{He}}$ and $v_{\text{ave,Kr}} > v_{\text{ave,He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$
 - D) Since $\lambda_{\text{Kr}} < \lambda_{\text{He}}$ and $v_{\text{ave,Kr}} > v_{\text{ave,He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$
 - E) Since $\lambda_{\text{Kr}} < \lambda_{\text{He}}$ and $v_{\text{ave,Kr}} < v_{\text{ave,He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$

Answer Key

1. E
2. B
3. D
4. B
5. C
6. B
7. E
8. E
9. E
10. B
11. C
12. C
13. B
14. D
15. B
16. B
17. A
18. B
19. D
20. E
21. C
22. E
23. B
24. B
25. E

CHEM 311 (141)

Final Exam

3 HOURS

Thursday, January 8, 2015, 7:00 PM

Building 10

Test Code (003)

(25 Questions)

Dr. Oweimreen	Section 1
Dr. Mazen Khaled	Section 2
Dr. Mohamed Morsy	Section 3
Dr. Foerner	Section 4

Physical constants, conversion factors, and useful equations

Physical Constants

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$= 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$$

$$= 0.08314 \text{ L bar K}^{-1} \text{ mol}^{-1}$$

$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$k_B = 1.381 \times 10^{-23} \text{ J K}^{-1}$$

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$F = 96,485 \text{ C mol}^{-1}$$

$$c = 2.998 \times 10^8 \text{ m s}^{-1}$$

$$g = 9.81 \text{ m s}^{-2}$$

$$e = 1.6022 \times 10^{-19} \text{ C}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$$

$$B = 0.51 \text{ mol}^{-1/2} \text{ dm}^{3/2} \text{ (in H}_2\text{O, 25}^\circ\text{C)}$$

Other Units

$$1 \text{ dm}^3 = 1 \text{ L}$$

$$1 \text{ dm}^3 = 1000 \text{ cm}^3$$

$$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

$$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa}$$

$$1 \text{ atm} = 760 \text{ mmHg}$$

$$1 \text{ Torr} = 1 \text{ mmHg}$$

$$1 \text{ Torr} = 133.322 \text{ Pa}$$

$$1 \text{ bar} = 10^5 \text{ Pa}$$

$$E = h\nu$$

$$c = \nu\lambda$$

$$PV = nRT$$

$$(RT)/F = 25.6926 \text{ mV at } 25^\circ\text{C}$$

$$\ln(x)/\log_{10}(x) = 2.30259 \text{ for all } x$$

$$\ln(1 - \theta) = -\theta$$

$$\text{if } \theta \ll 1$$

Quadratic equation:

$$a x^2 + b x + c = 0$$

solutions:

$$x_{1,2} = (1/2a)[-b \pm (b^2 - 4ac)^{1/2}]$$

$$RT/F = 25.70 \text{ mV (at } 25^\circ\text{C for ln)}$$

$$= 59.16 \text{ mV (at } 25^\circ\text{C for log}_{10})$$

Michaelis - Menten equation:

$$(1/R_0) = (1/R_{\max}) + (K_m/R_{\max}) \times (1/[S]_0)$$

Lindemann mechanism:

$$k_{\text{uni}} = k_1 k_2 [M] (k_{-1}[M] + k_2)^{-1}$$

Langmuir isotherm:

$$\theta = KP / (1 + KP)$$

$$1/R_0 = 1/R_{\max} + (K_m/R_{\max}) (1/[S]_0)$$

Sequential reactions:

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

$$[B] = (k_1 / (k_2 - k_1)) f(t) [A]_0$$

$$f(t) = \exp(-k_1 t) - \exp(-k_2 t)$$

Important Equations

$$\Lambda = \frac{\kappa}{c}, \alpha = \frac{\Lambda}{\Lambda_0} \text{ and } I = \frac{I}{2} \sum_i c_i z_i^2$$

$$\log_{10} \gamma_i = -z_i^2 B \sqrt{I} \text{ and } \log_{10} \gamma_{\pm} = -z_{\pm} / z_{\pm} / B \sqrt{I}$$

$$\Lambda_m = \Lambda_m^\circ - K (c/c_0)^{1/2} \text{ (strong)}$$

$$1/\Lambda_m = 1/\Lambda_m^\circ + c \Lambda_m / [(\Lambda_m^\circ)^2 K_a] \text{ (weak)}$$

$$\Delta G^\circ_{\text{solution}} = (1/\epsilon_r - 1) z^2 e^2 N_A / (8\pi \epsilon_0 r)$$

$$E = E^\circ - \frac{RT}{zF} \ln \left(\frac{[Y]^y [Z]^z}{[A]^a [B]^b} \right)^u$$

$$\Delta G = -nFE \text{ and thus } \Delta G^\circ = -nFE^\circ$$

$$\Delta S = nF(dE/dt)_p$$

$$a_{\pm}^{m+n} = a_+^m a_-^n \text{ for } A_m B_n$$

$$\kappa = [2e^2 N_A \times (1000 \text{ L m}^{-3}) / (\epsilon_0 k_B T)]^{1/2} \times [\rho_{\text{solvent}} / \epsilon_r]^{1/2}$$

$$E^\circ_{\text{AgCl/Ag}} = +0.222 \text{ V}$$

$$k = A e^{-E_a / RT}$$

$$k = \frac{k_B T}{h} e^{-\Delta^\ddagger G^\circ / RT}$$

$$E_a = \Delta^\ddagger H^\circ - P \Delta^\ddagger V^\circ + RT \text{ (sol)}$$

$$= \Delta^\ddagger H^\circ - \Sigma \nu RT + RT \text{ (gas)}$$

$$\Delta G^\ddagger = \Delta H^\ddagger - T \Delta S^\ddagger$$

$$t_{1/2} = (\ln 2) / k \text{ (1}^\text{st} \text{ order)}$$

fluorescence lifetime $t_f = (k_f + k_q[Q])^{-1}$

$$R_0 = k_2 [S]_0 [E]_0 / ([S]_0 + K_m),$$

$$K_m = (k_{-1} + k_2) / k_1$$

$$k_2 [E]_0 = R_{\max} = V$$

$$D = (1/3) v_{\text{ave}} \lambda$$

$$\kappa = (1/3) (C_{V,m} / N_A) v_{\text{ave}} N_p \lambda$$

$$PV = nRT = (N/N_A) RT,$$

$$(C_{V,m} / N_A) = (3/2) k_B$$

$$\eta = (1/3) v_{\text{ave}} N_p \lambda m$$

$$f = 6\pi \eta r = k_B T / D$$

$$v_{\text{ave}} = (8RT / (\pi M))^{1/2}$$

$$N_p \lambda = 1 / ((\sqrt{2}) \sigma),$$

$$\lambda = RT / (P N_A (\sqrt{2}) \sigma)$$

$$N_p = (N/V) = P N_A / (RT)$$

$$\sigma = \pi d^2$$

$$x_{\text{rms}} = \sqrt{(2Dt)} \quad (1\text{-Dimension})$$

$$r_{\text{rms}} = \sqrt{(6Dt)} \quad (3\text{-Dimension})$$

Poiseuille equation: $(\Delta V / \Delta t) = (\pi r^4 / (8\eta)) \Delta P / \Delta L$

Stokes-Einstein equation: $D = k_B T / (6\pi \eta r)$

if $r(\text{particle}) \gg r(\text{solvent molecule})$

Ostwald viscosimeter: $\eta = A \rho t$,

Capillary rise: $h = 2\gamma / (\rho g r)$

Note:

Quantum yield/efficiency = Φ = moles of product formed / moles of photons absorbed

- The conductivity of a 0.0312 M solution of a weak base is $1.53 \times 10^{-4} \text{ S cm}^{-1}$. If the sum of the limiting ionic conductance for BH^+ and OH^- is $237.0 \text{ S cm}^2 \text{ mol}^{-1}$, what is the value of the base dissociation constant K_b ?
 - 3.21×10^{-4}
 - 2.12×10^{-6}
 - 1.51×10^{-4}
 - 2.11×10^{-3}
 - 1.36×10^{-5}

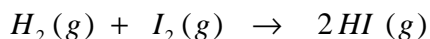
- Water is transported upward in trees through channels in the trunk called xylem. Although the diameter of the xylem channels varies from species to species, a typical value is $2.0 \times 10^{-7} \text{ m}$. If the water surface tension and density are $70.41 \times 10^{-3} \text{ N m}^{-1}$ and 997 kg m^{-3} , what will be the maximum transport height of the water to the top in the redwood tree?
 - 95.0 m
 - 214 m
 - 144 m
 - 21.0 m
 - 45.9 m

- Krypton (Kr) and Helium (He) are monatomic gases, and thus $C_{V,m} = 3/2 R$ for each. Given that $\sigma_{\text{Kr}} = 0.52 \text{ nm}^2$ and $\sigma_{\text{He}} = 0.28 \text{ nm}^2$ and that the molar mass of Kr is larger than that of He which one of the following is definitely correct?
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 - Since $\lambda_{\text{Kr}} < \lambda_{\text{He}}$ and $v_{\text{ave,Kr}} < v_{\text{ave,He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$
 - Since $\lambda_{\text{Kr}} < \lambda_{\text{He}}$ and $v_{\text{ave,Kr}} > v_{\text{ave,He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$
 - Actually $\kappa_{\text{Kr}} > \kappa_{\text{He}}$
 - Since $\lambda_{\text{Kr}} > \lambda_{\text{He}}$ and $v_{\text{ave,Kr}} > v_{\text{ave,He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$

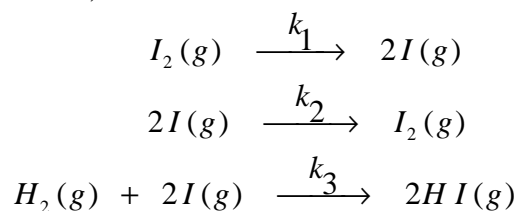
- Liquid A has half the surface tension and twice the density of liquid B, at 25 °C. If the capillary rise is 0.01 m for liquid A, then in the same capillary, the capillary rise for liquid B will be (assume complete wetting)
 - 0.04 m
 - 0.05 m
 - 0.01 m
 - 0.03 m
 - 0.02 m

5. The Arrhenius parameters for the unimolecular isomerization of methylcyanide,
- $$\text{CH}_3\text{NC}(g) \rightarrow \text{CH}_3\text{CN}(g)$$
- are an activation energy of 272 kJ/mol and a preexponential factor of $2.5 \times 10^{16} \text{ s}^{-1}$. Which of the following choices is completely correct for the ΔH^\ddagger (in kJ/mol) and ΔS^\ddagger (in J/(K mol)) values (from left to right) at 227 °C.
- A) 264, 63.0
 B) 276, 240
 C) 268, 56.4
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6. The viscosity of ethylene at 25 °C and 101.325 kPa is $9.33 \times 10^{-6} \text{ kg m}^{-1} \text{ s}^{-1}$. Estimate the molecular diameter of the ethylene molecule ($M_C = 12.01 \text{ g/mol}$, $M_H = 1.008 \text{ g/mol}$).
- A) 0.67 nm
 B) 1.19 nm
 C) 0.14 nm
 D) 2.22 nm
 E) 0.42 nm
7. Given the following Galvanic cell $\text{Zn}(s)|\text{Zn}^{2+}(\text{aq})||\text{Sn}^{4+}(\text{aq}),\text{Sn}^{2+}(\text{aq})|\text{Pt}(s)$. If the standard potential $E^0(\text{Zn}^{2+},\text{Zn}) = -0.76 \text{ V}$ and the standard cell potential $E^0_{\text{cell}} = 0.91 \text{ V}$, then the standard potential of the $\text{Sn}^{4+}/\text{Sn}^{2+}$ redox couple is:
- A) 1.50 V
 B) 1.67 V
 C) -0.15 V
 D) -1.67 V
 E) 0.15 V
8. Which of the following statements is not correct?
- A) The viscosities of liquids increase as temperature decreases.
 B) The viscosities of liquids obey a law of the Arrhenius type.
 C) For gases, viscosity is proportional to $T^{1/2}$, T being the temperature in Kelvin.
 D) The viscosities of gases decrease as temperature increases.
 E) The viscosities of gases increase as temperature increases.
9. The thermal conductivity of Helium, He, at 300 K and 1.00 atm is 0.0612 J/(K m s) . What is the mean free path length of He, assuming it to behave like an ideal gas ($M_{\text{He}} = 4.003 \text{ g/mol}$)?
- A) 9.11 μm
 B) 96 nm
 C) 3.0 μm
 D) 2.9 mm
 E) 288 nm

10. The reaction,



takes place in the presence of light. The mechanism which gives a rate law that agrees with experiment is,



The rate law is:

- A) $Rate = \frac{k_1 k_3 [H_2]}{k_2 + k_3 [HI]}$
B) $Rate = \frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [HI]}$
C) $Rate = \frac{k_1 k_3 [I_2]}{k_2 + k_3 [H_2]}$
D) $Rate = \frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [I_2]}$
E) $Rate = \frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [H_2]}$

11. The rate constant for the second order reaction between iodomethane, CH_3I , and ethoxy anions, $C_2H_5O^-$, in ethanol solution is $9.86 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$ at 25°C and $6.17 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$ at 65°C . Calculate the activation energy in kJ mol^{-1} units.

- A) 86.7
B) 40.0
C) 300
D) 116
E) 10.4

12. If the diffusion coefficient for insulin is $8.2 \times 10^{-11} \text{ m}^2 \text{ s}^{-1}$ at 20°C , estimate the mean time required for an insulin molecule to diffuse through a distance equal to the diameter of a typical living cell ($\sim 10 \mu\text{m}$).

- A) 0.61 s
B) 0.17 s
C) 2.1 s
D) 1.1 s
E) 3.2 s

13. The Galvanic cell $\text{Cu(s)}|\text{Cu}^{2+}(\text{aq})||\text{Ag}^{+}(\text{aq})|\text{Ag(s)}$ is based on the following cell reaction: $2\text{Ag}^{+}(\text{aq})+\text{Cu(s)}\rightarrow 2\text{Ag(s)}+\text{Cu}^{2+}(\text{aq})$. Note that $T = 298\text{ K}$ and the standard electrode potentials are $E^0(\text{Cu}^{2+},\text{Cu})=0.34\text{ V}$ and $E^0(\text{Ag}^{+},\text{Ag})=0.80\text{ V}$. Which of the following statements are correct?
- (i) The silver electrode is the cathode and the copper electrode is the anode.
 - (ii) Two moles of electrons flow through the external circuit from anode to cathode when the cell operates.
 - (iii) The standard cell potential is 0.46 V .
 - (iv) The change in Gibbs energy for the cell reaction is $-88,766\text{ J mol}^{-1}$ in the standard state.
- A) All statements are not correct.
 - B) (iii) and (iv) are correct.
 - C) (i) and (ii) are correct.
 - D) (i) is correct.
 - E) All statements are correct.
14. Thermopane windows filled with krypton (Kr , $M_{\text{Kr}} = 83.80\text{ g/mol}$) provide a ten times better heat insulation than normal windows filled with argon (Ar , $M_{\text{Ar}} = 39.95\text{ g/mol}$), advertisements claim. What is the ratio of the thermal conductivity of Kr ($\sigma = 0.52\text{ nm}^2$) to that of Ar ($\sigma = 0.36\text{ nm}^2$) and does it fulfill the advertisement claim of a ten times better heat insulation?
- A) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, fulfills the advertisement
 - B) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, does not fulfill the advertisement
 - C) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.33$, does not fulfill the advertisement
 - D) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 3.03$, fulfills the advertisement
 - E) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 2.09$, does not fulfill the advertisement
15. The densities of acetone and water at $20\text{ }^{\circ}\text{C}$ are 0.972 g cm^{-3} and 0.9982 g cm^{-3} , respectively. The viscosity of water is $1.002\times 10^{-3}\text{ Pa s}$ at $20\text{ }^{\circ}\text{C}$. If at $20\text{ }^{\circ}\text{C}$ water requires 120.5 s to run between the marks on a viscometer and acetone requires 40.5 s , what is the viscosity of acetone?
- A) $2.90\times 10^{-3}\text{ Pa s}$
 - B) $1.03\times 10^{-3}\text{ Pa s}$
 - C) $3.28\times 10^{-4}\text{ Pa s}$
 - D) $3.06\times 10^{-3}\text{ Pa s}$
 - E) $6.56\times 10^{-4}\text{ Pa s}$

16. For the protein myoglobin in water at 20 °C, the sedimentation coefficient is $s_{\text{sed}} = 2.04 \times 10^{-13}$ s, the diffusion coefficient is $D = 1.13 \times 10^{-10} \text{ m}^2 \text{ s}^{-1}$, and the specific volume is $0.740 \text{ cm}^3 \text{ g}^{-1}$. The density of water is 0.998 g cm^{-3} and its viscosity is 1.002 cP at the same temperature. Estimate the radius of myoglobin, assuming it to be spherical.
- A) 4.115 nm
 B) 1.897 nm
 C) 9.114 nm
 D) 3.150 nm
 E) 5.232 nm
17. At the same temperature and pressure, $D_{\text{Xe}} = 4.4 D_{\text{Rn}}$. What is the ratio, $\sigma_{\text{Rn}}/\sigma_{\text{Xe}}$, of their collisional cross sections if $M_{\text{Xe}} = 131.29 \text{ g/mol}$ and $M_{\text{Rn}} = 222 \text{ g/mol}$.
- A) 0.30
 B) 5.72
 C) 3.38
 D) 2.60
 E) 0.77
18. The flux of a property (J) is related to the gradient of the transported quantity (grad) as (α is the transport coefficient)
- A) J proportional to -grad
 B) J proportional to α^2
 C) J proportional to -1/grad
 D) J proportional to 1/grad
 E) J proportional to $1/\alpha$
19. The following reaction corresponds to eletroextraction of aluminum from aluminum ore:
- $$2/3\text{Al}_2\text{O}_3 \rightarrow 4/3\text{Al} + \text{O}_2, \quad \Delta G^0 = +966 \text{ kJ mol}^{-1}$$
- The minimum potential required to drive this reaction at 500°C is:
- A) 2.5V
 B) 5.0V
 C) 1.2V
 D) 4.5V
 E) 3.0V

20. The adsorption of an organic compound on an adsorbent measured at 5 °C and different pressures followed the Langmuir type of isotherm and a fit of $1/V_{ads}$ versus $1/P$ gave,

$$1/V_{ads} = 2.662 \text{ (torr/mL)} (1/P) + 0.203 \text{ (1/mL)}$$

where V_{ads} is the volume of the adsorbed organic compound in mL and P is its pressure in torr. The fractional coverage of charcoal at a pressure of 100 torr is,

- A) 0.884
B) 0.203
C) 0.612
D) 0.376
E) 0.430
21. The solubility product of K_2SO_4 is (γ_{\pm} is the mean activity coefficient):
- A) $4s^2\gamma_{\pm}^3$
B) $4s^3\gamma_{\pm}^3$
C) $4s^3\gamma_{\pm}^5$
D) $4s^5\gamma_{\pm}^3$
E) $4s^3\gamma_{\pm}^2$
22. What is the diffusion coefficient of xenon (Xe) at 298 K and a pressure of 2.00 atm, given the collisional cross section of Xe as $\sigma = 5.8 \times 10^{-19} \text{ m}^2$ and $M_{Xe} = 131.29 \text{ g/mol}$?
- A) $5.43 \times 10^{-6} \text{ m}^2/\text{s}$
B) $1.81 \times 10^{-6} \text{ m}^2/\text{s}$
C) $5.72 \times 10^{-8} \text{ m}^2/\text{s}$
D) $1.72 \times 10^{-7} \text{ m}^2/\text{s}$
E) $0.18 \text{ m}^2/\text{s}$
23. What is the ratio of the root mean square displacement in three dimensions (r_{rms}) to that in one dimension (x_{rms}) for a particle with $D = 3.41 \times 10^{-5} \text{ m}^2/\text{s}$ in 900 s in case of r_{rms} and in 1800s in case of x_{rms} ?
- A) $(3/2)^{1/2}$
B) $(6)^{1/2}$
C) $(2/3)^{1/2}$
D) $3/2$
E) $(1/6)^{1/2}$

24. Consider the photochemical decomposition:



With light at $\lambda = 253.7 \text{ nm}$, absorption of 3070 J of energy decomposed

$1.30 \times 10^{-2} \text{ mol HI}$. The quantum yield of this reaction is:

- A) 10^6
 - B) 5
 - C) 2
 - D) 0.5
 - E) 1
25. Given that the mean activity coefficient, γ_{\pm} , in a $0.100 \text{ mol kg}^{-1} \text{ MgBr}_2(\text{aq})$ solution is 0.524 at 25°C . Determine the percentage difference from the value predicted by the Debye-Hückel limiting law?
- A) 21%
 - B) 47%
 - C) 11%
 - D) 15%
 - E) 17%

Answer Key

1. E
2. C
3. B
4. A
5. C
6. E
7. E
8. D
9. E
10. E
11. A
12. A
13. E
14. B
15. C
16. B
17. C
18. A
19. A
20. A
21. B
22. B
23. A
24. C
25. B

CHEM 311 (141)

Final Exam

3 HOURS

Thursday, January 8, 2015, 7:00 PM

Building 10

Test Code (004)

(25 Questions)

Dr. Oweimreen	Section 1
Dr. Mazen Khaled	Section 2
Dr. Mohamed Morsy	Section 3
Dr. Foerner	Section 4

Physical constants, conversion factors, and useful equations

Physical Constants

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$= 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$$

$$= 0.08314 \text{ L bar K}^{-1} \text{ mol}^{-1}$$

$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$k_B = 1.381 \times 10^{-23} \text{ J K}^{-1}$$

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$F = 96,485 \text{ C mol}^{-1}$$

$$c = 2.998 \times 10^8 \text{ m s}^{-1}$$

$$g = 9.81 \text{ m s}^{-2}$$

$$e = 1.6022 \times 10^{-19} \text{ C}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$$

$$B = 0.51 \text{ mol}^{-1/2} \text{ dm}^{3/2} \text{ (in H}_2\text{O, 25}^\circ\text{C)}$$

Other Units

$$1 \text{ dm}^3 = 1 \text{ L}$$

$$1 \text{ dm}^3 = 1000 \text{ cm}^3$$

$$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

$$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa}$$

$$1 \text{ atm} = 760 \text{ mmHg}$$

$$1 \text{ Torr} = 1 \text{ mmHg}$$

$$1 \text{ Torr} = 133.322 \text{ Pa}$$

$$1 \text{ bar} = 10^5 \text{ Pa}$$

$$E = h\nu$$

$$c = \nu\lambda$$

$$PV = nRT$$

$$(RT)/F = 25.6926 \text{ mV at } 25^\circ\text{C}$$

$$\ln(x)/\log_{10}(x) = 2.30259 \text{ for all } x$$

$$\ln(1 - \theta) = -\theta$$

$$\text{if } \theta \ll 1$$

Quadratic equation:

$$a x^2 + b x + c = 0$$

solutions:

$$x_{1,2} = (1/2a)[-b \pm (b^2 - 4ac)^{1/2}]$$

$$RT/F = 25.70 \text{ mV (at } 25^\circ\text{C for ln)}$$

$$= 59.16 \text{ mV (at } 25^\circ\text{C for log}_{10})$$

Michaelis - Menten equation:

$$(1/R_0) = (1/R_{\max}) + (K_m/R_{\max}) \times (1/[S]_0)$$

Lindemann mechanism:

$$k_{\text{uni}} = k_1 k_2 [M] (k_{-1}[M] + k_2)^{-1}$$

Langmuir isotherm:

$$\theta = KP/(1 + KP)$$

$$1/R_0 = 1/R_{\max} + (K_m/R_{\max}) (1/[S]_0)$$

Sequential reactions:

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

$$[B] = (k_1/(k_2 - k_1)) f(t)[A]_0$$

$$f(t) = \exp(-k_1 t) - \exp(-k_2 t)$$

Important Equations

$$\Lambda = \frac{\kappa}{c}, \alpha = \frac{\Lambda}{\Lambda_0} \text{ and } I = \frac{I}{2} \sum_i c_i z_i^2$$

$$\log_{10} \gamma_i = -z_i^2 B \sqrt{I} \text{ and } \log_{10} \gamma_{\pm} = -z_{\pm} |z_{\pm}| B \sqrt{I}$$

$$\Lambda_m = \Lambda_m^\circ - K (c/c_0)^{1/2} \text{ (strong)}$$

$$1/\Lambda_m = 1/\Lambda_m^\circ + c \Lambda_m / [(\Lambda_m^\circ)^2 K_a] \text{ (weak)}$$

$$\Delta G^\circ_{\text{solution}} = (1/\epsilon_r - 1) z^2 e^2 N_A / (8\pi \epsilon_0 r)$$

$$E = E^\circ - \frac{RT}{zF} \ln \left(\frac{[Y]^y [Z]^z}{[A]^a [B]^b} \right)^u$$

$$\Delta G = -nFE \text{ and thus } \Delta G^\circ = -nFE^\circ$$

$$\Delta S = nF(dE/dt)_P$$

$$a_{\pm}^{m+n} = a_+^m a_-^n \text{ for } A_m B_n$$

$$\kappa = [2e^2 N_A \times (1000 \text{ L m}^{-3}) / (\epsilon_0 k_B T)]^{1/2} \times [\rho_{\text{solvent}} I / \epsilon_r]^{1/2}$$

$$E^\circ_{\text{AgCl/Ag}} = +0.222 \text{ V}$$

$$k = A e^{-E_a/RT}$$

$$k = \frac{k_B T}{h} e^{-\Delta^\ddagger G^\circ / RT}$$

$$E_a = \Delta^\ddagger H^\circ - P \Delta^\ddagger V^\circ + RT \text{ (sol)}$$

$$= \Delta^\ddagger H^\circ - \Sigma \nu RT + RT \text{ (gas)}$$

$$\Delta G^\ddagger = \Delta H^\ddagger - T \Delta S^\ddagger$$

$$t_{1/2} = (\ln 2)/k \text{ (1}^{\text{st}} \text{ order)}$$

fluorescence lifetime $t_f = (k_f + k_q[Q])^{-1}$

$$R_0 = k_2 [S]_0 [E]_0 / ([S]_0 + K_m),$$

$$K_m = (k_{-1} + k_2) / k_1$$

$$k_2 [E]_0 = R_{\max} = V$$

$$D = (1/3) v_{\text{ave}} \lambda$$

$$\kappa = (1/3) (C_{V,m}/N_A) v_{\text{ave}} N_p \lambda$$

$$PV = nRT = (N/N_A) RT,$$

$$(C_{V,m}/N_A) = (3/2) k_B$$

$$\eta = (1/3) v_{\text{ave}} N_p \lambda m$$

$$f = 6\pi\eta r = k_B T / D$$

$$v_{\text{ave}} = (8RT/(\pi M))^{1/2}$$

$$N_p \lambda = 1/((\sqrt{2})\sigma),$$

$$\lambda = RT/(PN_A(\sqrt{2})\sigma)$$

$$N_p = (N/V) = PN_A/(RT)$$

$$\sigma = \pi d^2$$

$$x_{\text{rms}} = \sqrt{(2Dt)} \quad (1\text{-Dimension})$$

$$r_{\text{rms}} = \sqrt{(6Dt)} \quad (3\text{-Dimension})$$

Poiseuille equation: $(\Delta V/\Delta t) = (\pi r^4/(8\eta)) \Delta P / \Delta L$

Stokes-Einstein equation: $D = k_B T / (6\pi \eta r)$

if $r(\text{particle}) \gg r(\text{solvent molecule})$

Ostwald viscosimeter: $\eta = \text{Apt}$,

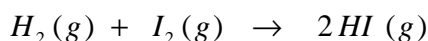
Capillary rise: $h = 2\gamma/(\rho g r)$

Note:

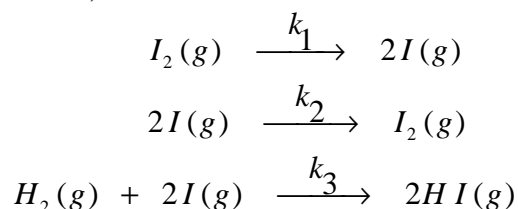
Quantum yield/efficiency = Φ = moles of product formed / moles of photons absorbed

1. Given that the mean activity coefficient, γ_{\pm} , in a 0.100 mol kg⁻¹ MgBr₂(aq) solution is 0.524 at 25°C. Determine the percentage difference from the value predicted by the Debye-Hückel limiting law?
- A) 17%
 B) 21%
 C) 47%
 D) 11%
 E) 15%

2. The reaction,



takes place in the presence of light. The mechanism which gives a rate law that agrees with experiment is,



The rate law is:

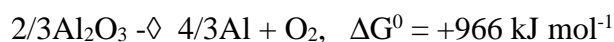
- A) $Rate = \frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [HI]}$
 B) $Rate = \frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [I_2]}$
 C) $Rate = \frac{k_1 k_3 [H_2]}{k_2 + k_3 [HI]}$
 D) $Rate = \frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [H_2]}$
 E) $Rate = \frac{k_1 k_3 [I_2]}{k_2 + k_3 [H_2]}$
3. The adsorption of an organic compound on an adsorbent measured at 5 °C and different pressures followed the Langmuir type of isotherm and a fit of $1/V_{ads}$ versus $1/P$ gave,

$$1/V_{ads} = 2.662 \text{ (torr/mL)} (1/P) + 0.203 \text{ (1/mL)}$$

where V_{ads} is the volume of the adsorbed organic compound in mL and P is its pressure in torr. The fractional coverage of charcoal at a pressure of 100 torr is,

- A) 0.203
 B) 0.612
 C) 0.430
 D) 0.884
 E) 0.376

4. The following reaction corresponds to electroextraction of aluminum from aluminum ore:



The minimum potential required to drive this reaction at 500°C is:

- A) 5.0V
B) 4.5V
C) 2.5V
D) 3.0V
E) 1.2V
5. What is the diffusion coefficient of xenon (Xe) at 298 K and a pressure of 2.00 atm, given the collisional cross section of Xe as $\sigma = 5.8 \times 10^{-19} \text{ m}^2$ and $M_{\text{Xe}} = 131.29 \text{ g/mol}$?
- A) $5.72 \times 10^{-8} \text{ m}^2/\text{s}$
B) $1.72 \times 10^{-7} \text{ m}^2/\text{s}$
C) $0.18 \text{ m}^2/\text{s}$
D) $5.43 \times 10^{-6} \text{ m}^2/\text{s}$
E) $1.81 \times 10^{-6} \text{ m}^2/\text{s}$
6. Consider the photochemical decomposition:
- $$2\text{HI} \rightarrow \text{H}_2 + \text{I}_2$$
- With light at $\lambda = 253.7 \text{ nm}$, absorption of 3070 J of energy decomposed $1.30 \times 10^{-2} \text{ mol HI}$. The quantum yield of this reaction is:
- A) 2
B) 0.5
C) 1
D) 10^6
E) 5
7. What is the ratio of the root mean square displacement in three dimensions (r_{rms}) to that in one dimension (x_{rms}) for a particle with $D = 3.41 \times 10^{-5} \text{ m}^2/\text{s}$ in 900 s in case of r_{rms} and in 1800s in case of x_{rms} ?
- A) $(1/6)^{1/2}$
B) $3/2$
C) $(6)^{1/2}$
D) $(3/2)^{1/2}$
E) $(2/3)^{1/2}$

8. The rate constant for the second order reaction between iodomethane, CH_3I , and ethoxy anions, $\text{C}_2\text{H}_5\text{O}^-$, in ethanol solution is $9.86 \times 10^{-5} \text{ mol dm}^{-3}\text{s}^{-1}$ at 25°C and $6.17 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$ at 65°C . Calculate the activation energy in kJ mol^{-1} units.
- 40.0
 - 10.4
 - 116
 - 86.7
 - 300
9. The solubility product of K_2SO_4 is (γ_{\pm} is the mean activity coefficient):
- $4s^3\gamma_{\pm}^3$
 - $4s^3\gamma_{\pm}^5$
 - $4s^5\gamma_{\pm}^3$
 - $4s^3\gamma_{\pm}^2$
 - $4s^2\gamma_{\pm}^3$
10. For the protein myoglobin in water at 20°C , the sedimentation coefficient is $s_{\text{sed}} = 2.04 \times 10^{-13} \text{ s}$, the diffusion coefficient is $D = 1.13 \times 10^{-10} \text{ m}^2 \text{ s}^{-1}$, and the specific volume is $0.740 \text{ cm}^3 \text{ g}^{-1}$. The density of water is 0.998 g cm^{-3} and its viscosity is 1.002 cP at the same temperature. Estimate the radius of myoglobin, assuming it to be spherical.
- 9.114 nm
 - 4.115 nm
 - 5.232 nm
 - 1.897 nm
 - 3.150 nm
11. The Galvanic cell $\text{Cu(s)} | \text{Cu}^{2+}(\text{aq}) || \text{Ag}^+(\text{aq}) | \text{Ag(s)}$ is based on the following cell reaction: $2\text{Ag}^+(\text{aq}) + \text{Cu(s)} \rightarrow 2\text{Ag(s)} + \text{Cu}^{2+}(\text{aq})$. Note that $T = 298 \text{ K}$ and the standard electrode potentials are $E^0(\text{Cu}^{2+}, \text{Cu}) = 0.34 \text{ V}$ and $E^0(\text{Ag}^+, \text{Ag}) = 0.80 \text{ V}$. Which of the following statements are correct?
- The silver electrode is the cathode and the copper electrode is the anode.
 - Two moles of electrons flow through the external circuit from anode to cathode when the cell operates.
 - The standard cell potential is 0.46 V .
 - The change in Gibbs energy for the cell reaction is $-88,766 \text{ J mol}^{-1}$ in the standard state.
- (iii) and (iv) are correct.
 - (i) and (ii) are correct.
 - (i) is correct.
 - All statements are correct.
 - All statements are not correct.

12. At the same temperature and pressure, $D_{Xe} = 4.4 D_{Rn}$. What is the ratio, σ_{Rn}/σ_{Xe} , of their collisional cross sections if $M_{Xe} = 131.29$ g/mol and $M_{Rn} = 222$ g/mol.
- A) 3.38
 B) 0.77
 C) 5.72
 D) 0.30
 E) 2.60
13. The densities of acetone and water at 20 °C are 0.972 g cm⁻³ and 0.9982 g cm⁻³, respectively. The viscosity of water is 1.002×10^{-3} Pa s at 20 °C. If at 20 °C water requires 120.5 s to run between the marks on a viscometer and acetone requires 40.5 s, what is the viscosity of acetone?
- A) 1.03×10^{-3} Pa s
 B) 3.28×10^{-4} Pa s
 C) 6.56×10^{-4} Pa s
 D) 2.90×10^{-3} Pa s
 E) 3.06×10^{-3} Pa s
14. The conductivity of a 0.0312 M solution of a weak base is 1.53×10^{-4} S cm⁻¹. If the sum of the limiting ionic conductance for BH⁺ and OH⁻ is 237.0 S cm² mol⁻¹, what is the value of the base dissociation constant K_b ?
- A) 1.51×10^{-4}
 B) 2.11×10^{-3}
 C) 2.12×10^{-6}
 D) 1.36×10^{-5}
 E) 3.21×10^{-4}
15. Krypton (Kr) and Helium (He) are monatomic gases, and thus $C_{V,m} = 3/2 R$ for each. Given that $\sigma_{Kr} = 0.52$ nm² and $\sigma_{He} = 0.28$ nm² and that the molar mass of Kr is larger than that of He which one of the following is definitely correct?
- A) Since $\lambda_{Kr} > \lambda_{He}$ and $v_{ave,Kr} > v_{ave,He}$ it follows that $\kappa_{Kr} < \kappa_{He}$
 B) Since $\lambda_{Kr} > \lambda_{He}$ and $v_{ave,Kr} < v_{ave,He}$ it follows that $\kappa_{Kr} < \kappa_{He}$
 C) Actually $\kappa_{Kr} > \kappa_{He}$
 D) Since $\lambda_{Kr} < \lambda_{He}$ and $v_{ave,Kr} < v_{ave,He}$ it follows that $\kappa_{Kr} < \kappa_{He}$
 E) Since $\lambda_{Kr} < \lambda_{He}$ and $v_{ave,Kr} > v_{ave,He}$ it follows that $\kappa_{Kr} < \kappa_{He}$

16. Thermopane windows filled with krypton (Kr, $M_{\text{Kr}} = 83.80 \text{ g/mol}$) provide a ten times better heat insulation than normal windows filled with argon (Ar, $M_{\text{Ar}} = 39.95 \text{ g/mol}$), advertisements claim. What is the ratio of the thermal conductivity of Kr ($\sigma = 0.52 \text{ nm}^2$) to that of Ar ($\sigma = 0.36 \text{ nm}^2$) and does it fulfill the advertisement claim of a ten times better heat insulation?
- A) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.33$, does not fulfill the advertisement
 - B) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 3.03$, fulfills the advertisement
 - C) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 2.09$, does not fulfill the advertisement
 - D) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, fulfills the advertisement
 - E) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, does not fulfill the advertisement
17. Liquid A has half the surface tension and twice the density of liquid B, at $25 \text{ }^\circ\text{C}$. If the capillary rise is 0.01 m for liquid A, then in the same capillary, the capillary rise for liquid B will be (assume complete wetting)
- A) 0.01 m
 - B) 0.03 m
 - C) 0.02 m
 - D) 0.04 m
 - E) 0.05 m
18. The thermal conductivity of Helium, He, at 300 K and 1.00 atm is $0.0612 \text{ J}/(\text{K m s})$. What is the mean free path length of He, assuming it to behave like an ideal gas ($M_{\text{He}} = 4.003 \text{ g/mol}$)?
- A) 3.0μ
 - B) $9.11 \mu\text{m}$
 - C) 2.9 mm
 - D) 288 nm
 - E) 96 nm
19. Which of the following statements is not correct?
- A) For gases, viscosity is proportional to $T^{1/2}$, T being the temperature in Kelvin.
 - B) The viscosities of gases decrease as temperature increases.
 - C) The viscosities of liquids obey a law of the Arrhenius type.
 - D) The viscosities of gases increase as temperature increases.
 - E) The viscosities of liquids increase as temperature decreases.

20. Water is transported upward in trees through channels in the trunk called xylem. Although the diameter of the xylem channels varies from species to species, a typical value is 2.0×10^{-7} m. If the water surface tension and density are $70.41 \times 10^{-3} \text{ N m}^{-1}$ and 997 kg m^{-3} , what will be the maximum transport height of the water to the top in the redwood tree?
- A) 21.0 m
 B) 95.0 m
 C) 45.9 m
 D) 144 m
 E) 214 m
21. The viscosity of ethylene at 25°C and 101.325 kPa is $9.33 \times 10^{-6} \text{ kg m}^{-1} \text{ s}^{-1}$. Estimate the molecular diameter of the ethylene molecule ($M_C = 12.01 \text{ g/mol}$, $M_H = 1.008 \text{ g/mol}$).
- A) 0.14 nm
 B) 2.22 nm
 C) 1.19 nm
 D) 0.42 nm
 E) 0.67 nm
22. If the diffusion coefficient for insulin is $8.2 \times 10^{-11} \text{ m}^2 \text{ s}^{-1}$ at 20°C , estimate the mean time required for an insulin molecule to diffuse through a distance equal to the diameter of a typical living cell ($\sim 10 \mu\text{m}$).
- A) 2.1 s
 B) 1.1 s
 C) 3.2 s
 D) 0.61 s
 E) 0.17 s
23. The Arrhenius parameters for the unimolecular isomerization of methylcyanide,
- $$\text{CH}_3\text{NC}(g) \rightarrow \text{CH}_3\text{CN}(g)$$
- are an activation energy of 272 kJ/mol and a preexponential factor of $2.5 \times 10^{16} \text{ s}^{-1}$. Which of the following choices is completely correct for the ΔH^\ddagger (in kJ/mol) and ΔS^\ddagger (in J/(K mol)) values (from left to right) at 227°C .
- A) 268, 56.4
 B) 272, 435
 C) 270, 63.0
 D) 264, 63.0
 E) 276, 240

24. Given the following Galvanic cell $\text{Zn(s)}|\text{Zn}^{2+}(\text{aq})||\text{Sn}^{4+}(\text{aq}),\text{Sn}^{2+}(\text{aq})|\text{Pt(s)}$. If the standard potential $E^0(\text{Zn}^{2+},\text{Zn}) = -0.76 \text{ V}$ and the standard cell potential $E^0_{\text{cell}} = 0.91 \text{ V}$, then the standard potential of the $\text{Sn}^{4+}/\text{Sn}^{2+}$ redox couple is:
- A) -1.67 V
 - B) -0.15 V
 - C) 150 V
 - D) 0.15 V
 - E) 1.67 V
25. The flux of a property (J) is related to the gradient of the transported quantity (grad) as (α is the transport coefficient)
- A) J proportional to α^2
 - B) J proportional to $-1/\text{grad}$
 - C) J proportional to $1/\text{grad}$
 - D) J proportional to $1/\alpha$
 - E) J proportional to $-\text{grad}$

Answer Key

1. C
2. D
3. D
4. C
5. E
6. A
7. D
8. D
9. A
10. D
11. D
12. A
13. B
14. D
15. D
16. E
17. D
18. D
19. B
20. D
21. D
22. D
23. A
24. D
25. E

Version 000

Thursday, January 8, 2014, 7 - 10 pm, Build. 10

Sec # 02: Dr. Morsy (29 students), SEC# 01: Dr. Khaled (16 students), Sec # 04: Dr. Foerner (20 students), Sec# 03: Dr. Oweimreen (30 students), 95 students all together)

Please give your section number below

STUDENT NAME : _____

STUDENT ID NUMBER: _____

STUDENT SECTION NUMBER: _____

Number of Correct Answers	Your Score out of 100%

Version 000

Solutions

all correct choices: A)

Diffusion coefficient for gases: $D = (1/3) v_{ave} \lambda$

From ideal gas theory: average speed

$$v_{ave} = (8RT/(\pi M))^{1/2}$$

M: molar mass of the diffusing particles

Mean free path: $\lambda = RT/(PN_A(\sqrt{2})\sigma)$

$\sigma = \pi d^2$: collisional cross section, d: particle diameter

root mean square displacement of particles during 1 dimensional diffusion in time t (=path moved):

$$x_{rms} = (\sqrt{\langle x^2 \rangle}) = \sqrt{(2Dt)}$$

root mean square displacement of particles during 3 dimensional diffusion in time t (=path moved):

$$x_{rms} = (\sqrt{\langle x^2 \rangle}) = \sqrt{(6Dt)}$$

thermal conductivity (gases): $\kappa = (1/3) (C_{v,m}/N_A) v_{ave} N_p \lambda$

N_p denotes the particle number density, ideal gases: $(C_{v,m}/N_A) = (3/2) k_B$ and

$N_p \lambda = 1/((\sqrt{2})\sigma)$, $PV = nRT = (N/N_A)RT$, thus $N_p = (N/N_A) = PN_A/(RT)$ (for ideal gases only) here: $N_p = \text{const}$ in the system

Gas viscosity: $\eta = (1/3) v_{ave} N_p \lambda m$, m being the mass of one particle ($m = M/N_A$)

Poiseuille equation for the rate of volume of a liquid through a tube of radius r and length L under a pressure difference ΔP : $(\Delta V/\Delta t) = (\pi r^4/(8\eta)) \Delta P/\Delta L$, ΔP = pressure drop along the tube

Stokes-Einstein equation: $D = k_B T/(6\pi \eta r)$ if $r(\text{particle}) \gg r(\text{solvent molecule})$ like for a protein

Ostwald Viscosimeter: $\eta = Adt$ (d=density, t flow time, A viscosimeter constant)

Capillary effect: $h = 2\gamma/(dgr)$, where d is the density of the liquid g the gravitational acceleration and r the capillary radius

Physical constants, conversion factors, and useful equations

Physical Constants

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$= 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$$

$$= 0.08314 \text{ L bar K}^{-1} \text{ mol}^{-1}$$

$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$k_B = 1.381 \times 10^{-23} \text{ J K}^{-1}$$

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$F = 96,500 \text{ C mol}^{-1}$$

$$c = 2.998 \times 10^8 \text{ m s}^{-1}$$

$$g = 9.81 \text{ m s}^{-2}$$

$$B = 0.51 \text{ mol}^{-1/2} \text{ dm}^{3/2} \text{ (in H}_2\text{O, 25}^\circ\text{C)}$$

Sequential reactions:

$$A \xrightarrow{(k_1)} B \xrightarrow{(k_2)} C$$

$$[B] = (k_1 / (k_2 - k_1)) f(t) [A]_0$$

$$f(t) = \exp(-k_1 t) - \exp(-k_2 t)$$

The inverse of the initial Michaelis Menten kinetics yields the Lineweaver-Burk equation:

$$1/R_0 = 1/R_{\max} + (K_m/R_{\max}) (1/[S]_0)$$

Other Units

$$1 \text{ dm}^3 = 1 \text{ L}$$

$$1 \text{ dm}^3 = 1000 \text{ cm}^3$$

$$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

$$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa}$$

$$1 \text{ atm} = 760 \text{ mmHg}$$

$$1 \text{ Torr} = 1 \text{ mmHg}$$

$$1 \text{ Torr} = 133.322 \text{ Pa}$$

$$1 \text{ bar} = 10^5 \text{ Pa}$$

$$0 \text{ degree Celcius is } 273.15 \text{ Kelvin}$$

Eyring equation:

$$k = k_B T / (hc^0) \times f$$

$$f = \exp(\Delta S^\ddagger / R) \times \exp(-\Delta H^\ddagger / RT)$$

$$\ln(1 - \theta) = -\theta$$

if $\theta \ll 1$

half life for 1. order reactions:
 $t_{1/2} = (\ln 2) / k$

Important Equations

$$E = h\nu$$

$$c = \nu\lambda$$

$$PV = nRT$$

$$\Delta G = \Delta H - T\Delta S$$

$$k = A e^{-E_a / RT}$$

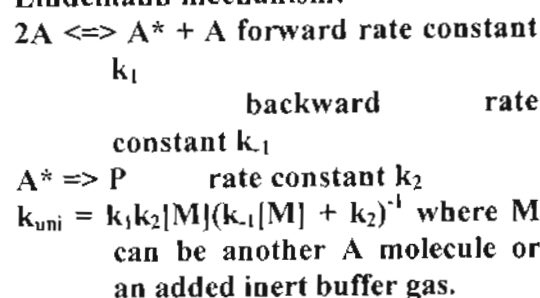
$$k = \frac{k_B T}{h} e^{-\Delta^\ddagger G / RT}$$

$$E_a = \Delta^\ddagger H^\circ - P\Delta^\ddagger V^\circ + RT \text{ (sol)}$$

$$= \Delta^\ddagger H^\circ - \Sigma \nu RT + RT \text{ (gas)}$$

fluorescence lifetime $t_f = (k_f + k_q[Q])^{-1}$
 Q is the quencher

Lindemann mechanism:



Langmuir isotherm (P is pressure, theta is fractional occupation):
 $\text{theta} = KP / (1 + KP)$, at $T = \text{const.}$

Michaelis-Menten kinetics:

$$R_0 = k_2 [S]_0 [E]_0 / ([S]_0 + K_m)$$

where S is the reactant (substrate) and E the enzyme

The inverse of R_0 yields the Lineweaver-Burk equation

$$K_m = (k_{-1} + k_2) / k_1 \quad \text{maximum rate:}$$

$$R_{\max} = V = k_2 [E]_0$$

Note:

- Quantum yield = Φ = moles of product formed / moles of photons absorbed

$$(RT)/F = 25.6926 \text{ mV at } 25^\circ\text{C for the ln form} \quad e = 1.6022 \times 10^{-19} \text{ C}$$

and $RT/F = 59.1595 \text{ mV at } 25^\circ\text{C for the log}_{10} \text{ form of the Nernst equation}$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$$

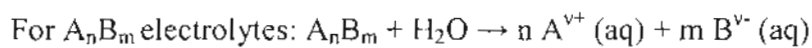
$$\text{strong: } \Lambda_m = \Lambda_m^\circ - K (c/c_0)^{1/2}$$

$$\text{weak: } 1/\Lambda_m = 1/\Lambda_m^\circ + c\Lambda_m / [(\Lambda_m^\circ)^2 K_a]$$

$$\text{Born model: } \Delta G_{\text{solvation}}^\circ = (1/\epsilon_r - 1) z^2 e^2 N_A / (8\pi\epsilon_0 r)$$

$$\text{Debye-Hückel Limiting Law (DHLL): } \log_{10} \gamma_{\pm} = -0.5092 |z_+ z_-| (I/M)^{1/2}$$

$$\text{or } \ln \gamma_{\pm} = -1.173 |z_+ z_-| (I/M)^{1/2}$$



$$\text{The solubility product is: } K_{sp} = (c_{A^{v+}}/c_0)^n (c_{B^{v-}}/c_0)^m \gamma_{\pm}^{m+n}$$

$$\Delta G = -nFE \quad \text{and thus } \Delta G^\circ = -nFE^\circ$$

$$\Delta S = nF(dE/dT)_p$$

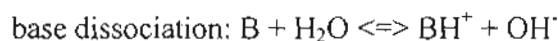
$$\Delta G = \Delta H - T \Delta S$$

$$a_{\pm}^{m+n} = a_+^m a_-^n \text{ for } A_n B_m$$

Inverse of the Debye-Hückel screening length (κ):

$$\kappa = [2e^2 N_A \times (1000 \text{ L m}^{-3}) / (\epsilon_0 k_B T)]^{1/2} \times [\rho_{\text{solvent}} I / \epsilon_r]^{1/2}$$

where I denotes the ionic strength of the solution, ρ_{solvent} the density of the solvent, and ϵ_r the relative dielectric constant of the solvent



The water concentration is large and thus constant

The initial concentration of base is $c_0 = [B]_0$

The hydrolyzed amount is $x = m/m_0$ with $m_0 = 1 \text{ mol/kg}$

Equilibrium constant $K = x^2 \gamma^2 / (c_0 - x)$ which yields x , γ is the mean activity coefficient of the two ions.

$$\text{Quadratic equation: } x^2 + px + q = 0 \text{ with solutions } x_{1,2} = (1/2)[-p + (\text{or } -) (p^2 - 4q)^{1/2}]$$

$$\lambda = \frac{RT}{P N_A \sqrt{2} \sigma}$$

Multiple choice

$$D = \frac{1}{3} v_{ave} \lambda \quad v_{ave} = \sqrt{\frac{8RT}{\pi M}}$$

$$\sqrt{\frac{\text{kg m}^2}{\text{s}^2}} = \frac{\text{m}}{\text{s}} \quad v_{ave} = \sqrt{\frac{8 \cdot 8.314 \frac{\text{J}}{\text{K mol}} \cdot 298 \text{ K}}{\pi \cdot 0.13129 \text{ kg/mol}}} = 219.21 \frac{\text{m}}{\text{s}}$$

1. What is the diffusion coefficient of xenon (Xe) at 298 K and a pressure of 2.00 atm, given the collisional cross section of Xe as $\sigma = 5.8 \times 10^{-19} \text{ m}^2$ and $M_{Xe} = 131.29 \text{ g/mol}$?

- A) $1.81 \times 10^{-6} \text{ m}^2/\text{s}$
- B) $5.43 \times 10^{-6} \text{ m}^2/\text{s}$
- C) $1.72 \times 10^{-7} \text{ m}^2/\text{s}$
- D) $5.72 \times 10^{-8} \text{ m}^2/\text{s}$
- E) $0.18 \text{ m}^2/\text{s}$

$$\lambda = \frac{8.314 \frac{\text{J}}{\text{K mol}} \cdot 298 \text{ K}}{2 \text{ atm} \cdot 101325 \frac{\text{Pa}}{\text{atm}} \cdot 6.022 \cdot 10^{23} \frac{1}{\text{mol}} \sqrt{2} \cdot (5.8 \cdot 10^{-19} \text{ m}^2)}$$

$$= 2.475 \cdot 10^{-8} \text{ m} \quad \frac{\text{kg m}^2}{\text{s}^2 \cdot \text{mol}^2 \cdot \text{m}^2} = \text{m}$$

Ans: A

$$D = \frac{1}{3} v_{ave} \cdot \lambda = \frac{1}{3} 219.21 \frac{\text{m}}{\text{s}} \cdot 2.475 \cdot 10^{-8} \text{ m} = 1.808 \cdot 10^{-6} \frac{\text{m}^2}{\text{s}}$$

$$= 1.81 \cdot 10^{-6} \frac{\text{m}^2}{\text{s}}$$

Multiple choice

2. At the same temperature and pressure, $D_{Xe} = 4.4 D_{Rn}$. What is the ratio, σ_{Rn}/σ_{Xe} , of their collisional cross sections if $M_{Xe} = 131.29 \text{ g/mol}$ and $M_{Rn} = 222 \text{ g/mol}$?

- A) 3.38
- B) 0.77
- C) 5.72
- D) 0.30
- E) 2.60

$$\frac{D_{Xe}}{D_{Rn}} = 4.4 = \frac{\frac{1}{3} v_{ave, Xe} \lambda_{Xe}}{\frac{1}{3} v_{ave, Rn} \lambda_{Rn}} = \sqrt{\frac{M_{Rn}}{M_{Xe}}} \cdot \frac{\sigma_{Rn}}{\sigma_{Xe}}$$

Ans: A

$$\frac{\sigma_{Rn}}{\sigma_{Xe}} = 4.4 \cdot \sqrt{\frac{M_{Xe}}{M_{Rn}}} = 4.4 \cdot \sqrt{\frac{131.29}{222}} = 3.384$$

$$= 3.38$$

Multiple choice

$$\frac{x_{rms, 900s}}{x_{rms, 1800s}} = \sqrt{\frac{60 \cdot 900 \text{ s}}{20 \cdot 1800 \text{ s}}} = \sqrt{3 \cdot \frac{1}{2}} = \sqrt{3/2}$$

3. What is the ratio of the root mean square displacement in three dimensions (r_{rms}) to that in one dimension (x_{rms}) for a particle with $D = 3.41 \times 10^{-5} \text{ m}^2/\text{s}$ in 900 s in case of r_{rms} and in 1800s in case of x_{rms} ?

- A) $(3/2)^{1/2}$
- B) $(2/3)^{1/2}$
- C) $(6)^{1/2}$

D) $(1/6)^{1/2}$

E) $3/2$

Ans: A

$$\lambda = \frac{0.0612 \frac{\text{J}}{\text{K m s}}}{\frac{1}{2} \cdot 1.381 \cdot 10^{-23} \frac{\text{J}}{\text{K}} \cdot 1259.6 \frac{\text{m}}{\text{s}} \cdot 2.446 \cdot 10^{\frac{25}{23}}}$$

$$= 2.877 \cdot 10^{-7} \text{ m}$$

$$= 2.88 \cdot 10^2 \cdot 10^{-9} \text{ m} = 288 \text{ nm}$$

Multiple choice

4. The thermal conductivity of Helium, He, at 300 K and 1.00 atm is 0.0612 J/(K m s). What is the mean free path length of He, assuming it to behave like an ideal gas

($M_{\text{He}} = 4.003 \text{ g/mol}$)?

A) 288 nm

B) 9.11 μm

C) 2.9 mm

D) 96 nm

E) 3.0 μm

Ans: A

$$k = \frac{1}{3} \frac{C_{v,m}}{N_A} v_{\text{ave}} \frac{P N_A}{RT} \lambda$$

$$\frac{C_{v,m}}{N_A} = \frac{3}{2} k_B \text{ (ideal gas)}$$

$$\lambda = \frac{\frac{C_{v,m}}{N_A} v_{\text{ave}} \frac{P N_A}{RT}}{k}$$

$$v_{\text{ave}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8 \cdot 8.314 \frac{\text{J}}{\text{K mol}} \cdot 300 \text{ K}}{\pi \cdot 4.003 \cdot 10^{-3} \frac{\text{kg}}{\text{mol}}}}$$

$$= 1259.6 \frac{\text{m}}{\text{s}}$$

Multiple choice

$$\frac{P N_A}{RT} = \frac{1 \text{ atm} \cdot 101325 \frac{\text{Pa}}{\text{atm}} \cdot 6.022 \cdot 10^{23} \frac{1}{\text{mol}}}{8.314 \frac{\text{J}}{\text{K mol}} \cdot 300 \text{ K}} = 2.446 \cdot 10^{\frac{25}{23}} \frac{\text{N}}{\text{m}^2}$$

5. The flux of a property (J) is related to the gradient of the transported quantity = $2.446 \cdot 10^{\frac{25}{23}} \frac{1}{\text{m}^3}$ (grad) as (α is the transport coefficient)

A) J proportional to -grad

B) J proportional to α^2

C) J proportional to -1/grad

D) J proportional to 1/grad

E) J proportional to $1/\alpha$

Ans: A

$$J = -\alpha \text{ -grad}$$

Multiple choice

6. Thermopane windows filled with krypton (Kr , $M_{\text{Kr}} = 83.80 \text{ g/mol}$) provide a ten times better heat insulation than normal windows filled with argon (Ar , $M_{\text{Ar}} = 39.95 \text{ g/mol}$), advertisements claim. What is the ratio of the thermal

$$\kappa = \frac{1}{3} \frac{C_{v,m}}{N_A} v_{ave} N_P \lambda$$
 conductivity of Kr ($\sigma = 0.52 \text{ nm}^2$) to that of Ar ($\sigma = 0.36 \text{ nm}^2$) and does it fulfill the advertisement claim of a ten times better heat insulation?

monatomic gases: $C_{v,m}$ same

✓ (A) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, does not fulfill the advertisement
 B) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.478$, fulfills the advertisement
 C) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 2.09$, does not fulfill the advertisement
 D) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 3.03$, fulfills the advertisement
 E) $\kappa(\text{Kr})/\kappa(\text{Ar}) = 0.33$, does not fulfill the advertisement

$$\frac{\kappa_{\text{Kr}}}{\kappa_{\text{Ar}}} = \frac{(N_P \lambda)_{\text{Kr}} \cdot v_{ave, \text{Kr}}}{(N_P \lambda)_{\text{Ar}} \cdot v_{ave, \text{Ar}}} = \left(\frac{\sigma_{\text{Ar}}}{\sigma_{\text{Kr}}} \right) \cdot \frac{\sqrt{8RT/(\pi M_{\text{Kr}})}}{\sqrt{8RT/(\pi M_{\text{Ar}})}}$$

$$N_P \lambda = \frac{1}{\sqrt{2} \sigma}$$

$$\text{Ans: A} \quad = \left(\frac{\sigma_{\text{Ar}}}{\sigma_{\text{Kr}}} \right) \sqrt{\frac{M_{\text{Ar}}}{M_{\text{Kr}}}} = \frac{0.36}{0.52} \sqrt{\frac{39.95}{83.80}} = 0.478$$

Multiple choice $10\times$ better insulation requires that

$\kappa_{\text{Kr}} = \frac{1}{10} \kappa_{\text{Ar}}$, not 0.478

and thus

7. Krypton (Kr) and Helium (He) are monatomic gases $C_{v,m} = 3/2 R$ for each. Given that $\sigma_{\text{Kr}} = 0.52 \text{ nm}^2$ and $\sigma_{\text{He}} = 0.28 \text{ nm}^2$ and that the molar mass of Kr is larger than that of He which one of the following is definitely correct?

- ✓ (A) Since $\lambda_{\text{Kr}} < \lambda_{\text{He}}$ and $v_{ave, \text{Kr}} < v_{ave, \text{He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$
 B) Since $\lambda_{\text{Kr}} > \lambda_{\text{He}}$ and $v_{ave, \text{Kr}} < v_{ave, \text{He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$
 C) Since $\lambda_{\text{Kr}} < \lambda_{\text{He}}$ and $v_{ave, \text{Kr}} > v_{ave, \text{He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$
 D) Since $\lambda_{\text{Kr}} > \lambda_{\text{He}}$ and $v_{ave, \text{Kr}} > v_{ave, \text{He}}$ it follows that $\kappa_{\text{Kr}} < \kappa_{\text{He}}$
 E) Actually $\kappa_{\text{Kr}} > \kappa_{\text{He}}$

$$\lambda = \frac{RT}{P N_A \sqrt{2} \sigma}$$

$$\frac{\lambda_{\text{He}}}{\lambda_{\text{Kr}}} = \frac{\sigma_{\text{Kr}}}{\sigma_{\text{Ar}}} = \frac{0.52}{0.28}$$

$$= 1.86$$

$$\Rightarrow \lambda_{\text{He}} = 1.86 \lambda_{\text{Kr}} \Rightarrow \lambda_{\text{Kr}} < \lambda_{\text{He}}$$

Ans: A $\frac{v_{ave, \text{He}}}{v_{ave, \text{Kr}}} = \sqrt{\frac{M_{\text{Kr}}}{M_{\text{He}}}} > 1$, since $M_{\text{Kr}} > M_{\text{He}}$

$$\Rightarrow v_{ave, \text{He}} > v_{ave, \text{Kr}}$$

Multiple choice

$$\kappa = \frac{1}{3} \frac{C_{v,m}}{N_A} v_{ave} N_P \lambda \Rightarrow \kappa_{\text{Kr}} < \kappa_{\text{He}}$$

8. The adsorption of an organic compound on an adsorbent measured at 5°C and different pressures followed the Langmuir type of isotherm and a fit of $1/V_{ads}$ versus $1/P$ gave,

$$1/V_{ads} = 2.662 \left(\frac{1}{P} \right) + 0.203 \quad \left(\frac{\text{torr mL}}{\text{torr mL}} \right)$$

where V_{ads} is the volume of the adsorbed organic compound in mL and P is its pressure in torr. The fractional coverage of charcoal at a pressure of 100 torr is,

✓ (A) 0.884

$$\theta = \frac{V_{m,ads}}{V_{m,m}} = \frac{KP}{1+KP} \cdot \frac{1}{V_{ad}} = \frac{1}{KV_m} \cdot \frac{1}{P} + \frac{1}{V_m}$$

B) 0.376

C) 0.430

D) 0.203

E) 0.612

$$V_m = \frac{1}{0.203} \text{ mL} = 4.9261 \text{ mL}$$

$$K \frac{1}{KV_m} = 2.662 \frac{\text{torr}}{\text{mL}} \quad K = \frac{1}{2.662 \frac{\text{torr}}{\text{mL}} \cdot 4.9261 \text{ mL}} = 0.07626 \frac{1}{\text{torr}}$$

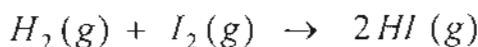
Ans: A

$$\theta = \frac{KP}{1+KP} = \frac{0.07626 \frac{1}{\text{torr}} \cdot 100 \text{ torr}}{1 + 0.07626 \cdot 100} = 0.8841$$

Multiple choice

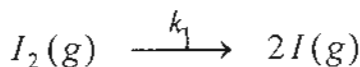
$$= 0.884$$

9. The reaction,

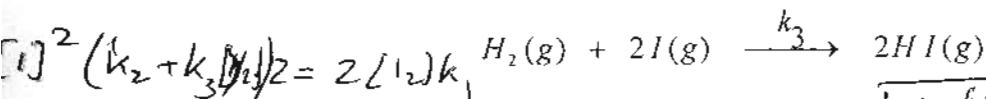
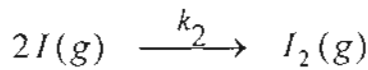


takes place in the presence of light. The mechanism which gives a rate law that agrees with experiment is,

$$SSA: \frac{d[I]}{dt} = 0$$



$$0 = 2[I_2]k_1 - 2k_2[I]^2 - 2k_3[H_2][I]^2$$



The rate law is:

$$\Rightarrow [I] = \sqrt{\frac{k_1[I_2]}{k_2 + k_3[H_2]}}$$

✓ A) Rate = $\frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [H_2]}$

B) Rate = $\frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [I_2]}$

C) Rate = $\frac{k_1 k_3 [I_2]}{k_2 + k_3 [H_2]}$

D) Rate = $\frac{k_1 k_3 [H_2][I_2]}{k_2 + k_3 [HI]}$

E) Rate = $\frac{k_1 k_3 [H_2]}{k_2 + k_3 [HI]}$

$$\text{Rate} = \frac{1}{2} \frac{d[HI]}{dt} = k_3 [H_2][I]^2 = \frac{k_1 \cdot k_3}{k_2 + k_3 [H_2]} [H_2][I_2]$$

Ans: A

Arrhenius: $k_1 = Ae^{-E_a/RT_1}$

$k_2 = Ae^{-E_a/RT_2}$

Multiple choice

$$\frac{k_1}{k_2} = e^{\frac{E_a}{R} \left(-\frac{1}{T_1} + \frac{1}{T_2} \right)} = e^{\frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)}$$

10. The rate constant for the second order reaction between iodomethane, CH_3I , and ethoxy anions, $\text{C}_2\text{H}_5\text{O}^-$, in ethanol solution is $9.86 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$ at 25°C and $6.17 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$ at 65°C . Calculate the activation energy in kJ mol^{-1} units.

$T_1 = 298.15 \text{ K}$
 $k_1 = 9.86 \cdot 10^{-5} \frac{1}{\text{M}}$
 $T_2 = 338.15 \text{ K}$
 $k_2 = 6.17 \cdot 10^{-3} \frac{1}{\text{M}}$

$$\frac{E_a}{R} = \frac{\ln k_1/k_2}{\frac{1}{T_2} - \frac{1}{T_1}} \quad E_a = \frac{R \ln k_1/k_2}{\frac{1}{T_2} - \frac{1}{T_1}}$$

- A) 86.7
- B) 116
- C) 300
- D) 10.4
- E) 40.0

Ans: A

$$E_a = \frac{8,314 \frac{\text{J}}{\text{Kmol}} \cdot \ln \frac{9.86 \cdot 10^{-5}}{6.17 \cdot 10^{-3}}}{\left(\frac{1}{338.15} - \frac{1}{298.15} \right) \frac{1}{\text{K}}} = 86679 \frac{\text{J}}{\text{mol}} = 86.7 \frac{\text{kJ}}{\text{mol}}$$

Multiple choice

$$k = \frac{k_B T}{h e^c} e^{\Delta S^\ddagger/R} e^{-\Delta H^\ddagger/RT}$$

unimolecular reaction

$$\Delta H^\ddagger = E_a - RT$$

11. The Arrhenius parameters for the unimolecular isomerization of methylcyanide,



$T = 500.15 \text{ K}$

are an activation energy of ~~272~~ 272 kJ mol^{-1} and a preexponential factor of

$2.5 \times 10^{16} \text{ s}^{-1}$. Which of the following choices is completely correct for the ΔH^\ddagger (in kJ/mol) and ΔS^\ddagger (in J/(K mol)) values (from left to right) at ~~227~~ 227°C .

- A) 268, 56.4
- B) 270, 63.0
- C) 264, 63.0
- D) 272, 435
- E) 276, 240

$$\Delta H^\ddagger = E_a - RT = 272 \frac{\text{kJ}}{\text{mol}} - 8,314 \cdot 10^{-3} \frac{\text{kJ}}{\text{Kmol}} \cdot 500.15 \text{ K} = 267.84 \frac{\text{kJ}}{\text{mol}} = 268 \frac{\text{kJ}}{\text{mol}}$$

- A) 268, 56.4
- B) 270, 63.0
- C) 264, 63.0
- D) 272, 435
- E) 276, 240

$$\Delta S^\ddagger = R \ln \frac{hA}{ek_B T} = 8,314 \frac{\text{J}}{\text{Kmol}} \cdot \ln \frac{6.626 \cdot 10^{-34} \text{ Js} \cdot 2.5 \cdot 10^{16} \text{ s}^{-1}}{e \cdot 1,381 \cdot 10^{-23} \frac{\text{J}}{\text{K}} \cdot 500.15 \text{ K}} = 8,314 \frac{\text{J}}{\text{Kmol}} \ln(882.27)$$

Ans: A

$$= 8,314 \frac{\text{J}}{\text{Kmol}} \cdot 6.7825 = 56.39 \frac{\text{J}}{\text{Kmol}} = 56.4 \frac{\text{J}}{\text{Kmol}}$$

$$E_{\text{phct}} = h\nu = \frac{hc}{\lambda} = \frac{6.626 \cdot 10^{-34} \text{ J} \cdot 2.998 \cdot 10^8 \frac{\text{m}}{\text{s}}}{253.7 \cdot 10^{-9} \text{ m}}$$

Multiple choice

$$= 7.830 \cdot 10^{-19} \text{ J}$$

12. Consider the photochemical decomposition: $N_{\text{phct}} = \frac{E}{E_{\text{phct}}} = \frac{3070 \text{ J}}{7.830 \cdot 10^{-19} \text{ J}} = 3,921 \cdot 10^{21}$

$$2\text{HI} \rightarrow \text{H}_2 + \text{I}_2$$

With light at $\lambda = 253.7 \text{ nm}$, absorption of 3070 J of energy decomposed

$1.30 \times 10^{-2} \text{ mol HI}$. The quantum yield of this reaction is: $\eta_{\text{phct}} = \frac{N_{\text{phct}}}{N_A}$

✓ A) 2

B) 1

C) 5

D) 10^6

E) 0.5

$$\eta_{\text{phct}} = \frac{3,921 \cdot 10^{21}}{6.022 \cdot 10^{23} \frac{\text{L}}{\text{mol}}} = 6.511 \cdot 10^{-3} \text{ mol} = 6.511 \text{ mmol}$$

$$n_{\text{mol}} = 1.30 \cdot 10^{-2} \text{ mol HI} = 13.0 \text{ mmol}$$

$$\phi = \frac{n_{\text{mol}}}{\eta_{\text{phct}}} = \frac{13.0}{6.511} = 1.997 = 2$$

Ans: A

Multiple choice

13. If the diffusion coefficient for insulin is $8.2 \times 10^{-11} \text{ m}^2 \text{ s}^{-1}$ at 20°C , estimate the mean time required for an insulin molecule to diffuse through a distance equal to the diameter of a typical living cell ($\sim 10 \mu\text{m}$).

$$s = \sqrt{2Dt}$$

✓ A) 0.61 s

B) 0.17 s

C) 2.1 s

D) 1.1 s

E) 3.2 s

$$(10 \cdot 10^{-6} \text{ m})^2 = 2 \cdot 8.2 \cdot 10^{-11} \frac{\text{m}^2}{\text{s}} t$$

$$1 \cdot 10^{-10} \text{ m}^2 = 16.4 \cdot 10^{-11} \frac{\text{m}^2}{\text{s}} t$$

$$t = \frac{1 \cdot 10^{-10} \text{ m}^2}{16.4 \cdot 10^{-11} \frac{\text{m}^2}{\text{s}}} = 0.6098 \text{ s} = 0.61 \text{ s}$$

Ans: A

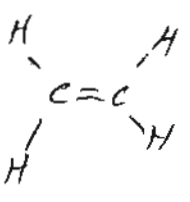
Multiple choice

$$\eta = \frac{1}{3} v_{ave} N_p l \cdot m \quad N_p l = \frac{1}{\sqrt{2} \sigma}$$

$$v_{ave} = \sqrt{\frac{8RT}{\pi M}}$$

14. The viscosity of ethylene at 25 °C and 101.325 kPa is $9.33 \times 10^{-6} \text{ kg m}^{-1} \text{ s}^{-1}$.

Estimate the molecular diameter of the ethylene molecule ($M_c = 12.01 \text{ g/mol}$)



A) 0.42 nm ✓

B) 0.14 nm

C) 0.67 nm

D) 1.19 nm

E) 2.22 nm

$M = (2 \cdot 12.01 + 4 \cdot 1.008) \text{ g/mol}$
 $= 28.052 \text{ g/mol}$
 $= 0.028052 \text{ kg/mol}$

Ans: A

$$M_H = 1.008 \text{ g/mol} \quad \mu$$

$$v_{ave} = \sqrt{\frac{8 \cdot 8.314 \frac{\text{J}}{\text{K mol}} \cdot 298.15 \text{ K}}{\pi \cdot 0.028052 \text{ kg/mol}}} = 474.36 \frac{\text{m}}{\text{s}}$$

$$\eta = \frac{1}{3} v_{ave} N_p l \cdot m = \frac{1}{3} v_{ave} \frac{1}{\sqrt{2} \sigma} \cdot \frac{M}{N_A}$$

$$\sigma = \frac{v_{ave} M}{3 N_A \sqrt{2} \eta} = \frac{474.36 \frac{\text{m}}{\text{s}} \cdot 0.028052 \text{ kg/mol}}{3 \cdot 6.022 \cdot 10^{23} \frac{1}{\text{mol}} \cdot 9.33 \cdot 10^{-6} \frac{\text{kg}}{\text{m s}}}$$

$$= 5.582 \cdot 10^{-10} \text{ m}$$

$$\sigma = \pi d^2$$

Multiple choice

$$d = \sqrt{\frac{\sigma}{\pi}} = \sqrt{\frac{5.582 \cdot 10^{-10} \text{ m}^2}{\pi}} = 4.215 \cdot 10^{-10} \text{ m}$$

$$= 0.42 \text{ nm}$$

15. For the protein myoglobin in water at 20 °C, the sedimentation coefficient is $s_{sed} =$

$2.04 \times 10^{-13} \text{ s}$, the diffusion coefficient is $D = 1.13 \times 10^{-10} \text{ m}^2 \text{ s}^{-1}$, and the specific $T = 293.15 \text{ K}$

volume is $0.740 \text{ cm}^3 \text{ g}^{-1}$. The density of water is 0.998 g cm^{-3} and its viscosity is 1.002

cP at the same temperature. Estimate the radius of myoglobin, assuming it to be

spherical.

$$r = \frac{1.381 \cdot 10^{-23} \text{ J/K} \cdot 293.15 \text{ K}}{6\pi \cdot 1.002 \cdot 10^{-2} \frac{\text{kg}}{\text{m s}} \cdot 1.13 \cdot 10^{-10} \frac{\text{m}^2}{\text{s}}}$$

A) 1.897 nm ✓

B) 3.150 nm

C) 4.115 nm

D) 5.232 nm

E) 9.114 nm

Ans: A

$$= 1.8969 \cdot 10^{-9} \text{ m} = 1.897 \text{ nm}$$

Multiple choice

$$f = \frac{m(1 - \bar{v}d)}{s_{sed}} = 6\pi\eta r \quad r = \frac{m(1 - \bar{v}d)}{6\pi\eta s_{sed}}$$

$$M = \frac{RT s_{sed}}{D(1 - \bar{v}d)}$$

11

$$= \frac{M(1 - \bar{v}d)}{6\pi\eta N_A s_{sed}} = \frac{RT s_{sed}(1 - \bar{v}d)}{6\pi\eta N_A D(1 - \bar{v}d) s_{sed}}$$

$$r = \frac{k_B T}{6\pi\eta D}$$

$$\Rightarrow r = \frac{RT}{6\pi\eta D N_A}$$

$$c = 0.0312 \text{ M} = 0.0312 \frac{\text{mol}}{\text{dm}^3} = 0.0312 \frac{\text{mol}}{(10 \text{ cm})^3} = 0.0312 \cdot 10^{-3} \frac{\text{mol}}{\text{cm}^3}$$

16. The conductivity of a 0.0312 M solution of a weak base is $1.53 \times 10^{-4} \text{ S cm}^{-1}$. If the sum of the limiting ionic conductance for BH^+ and OH^- is $237.0 \text{ S cm}^2 \text{ mol}^{-1}$, what is the value of the base dissociation constant K_b ?

✓ A) 1.36×10^{-5}

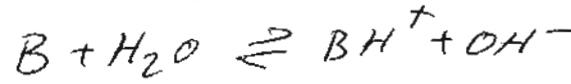
B) 2.11×10^{-3}

C) 3.21×10^{-4}

D) 1.51×10^{-4}

E) 2.12×10^{-6}

Ans: A



$$K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}$$

$$\frac{\Lambda}{\Lambda_m} = \frac{\Lambda^0}{\Lambda_m} + \frac{c\Lambda_m}{K_b(\Lambda_m^0)^2} \left(\frac{1}{\Lambda_m} - \frac{1}{\Lambda_m^0} \right) = \frac{c\Lambda_m}{K_b(\Lambda_m^0)^2}$$

$$K_b = \frac{\Lambda_m \Lambda_m^0}{\Lambda_m^0 - \Lambda_m} \cdot c \frac{\Lambda_m}{(\Lambda_m^0)^2} \Rightarrow \Lambda_m = \frac{K}{c}$$

Multiple choice

$$\Lambda_m = \frac{1.53 \cdot 10^{-4} \text{ S/cm}^2}{0.0312 \cdot 10^{-3} \frac{\text{mol}}{\text{cm}^3}} = 4.90 \frac{\text{S}}{\text{cm}^2 \text{ mol}}$$

$$K_b = \frac{4.90 \cdot 237}{237 - 4.9} \cdot 0.0312 \text{ M} \cdot \frac{4.9}{237^2} = 1.362 \cdot 10^{-5}$$

17. Liquid A has half the surface tension and twice the density of liquid B, at 25°C . If the capillary rise is 0.01 m for liquid A, then in the same capillary, the capillary rise for liquid B will be

$$h = \frac{2\gamma}{d\rho r}$$

✓ A) 0.04 m

B) 0.01 m

C) 0.02 m

D) 0.03 m

E) 0.05 m

Ans: A

$$\frac{h_A}{h_B} = \frac{\gamma_A}{\gamma_B} \frac{d_B}{d_A}$$

$$\gamma_A = \frac{1}{2}\gamma_B \quad d_A = 2d_B$$

$$\frac{h_B}{h_A} = \frac{\gamma_B}{\gamma_A} \cdot \frac{d_A}{d_B} = \frac{\gamma_B}{\frac{1}{2}\gamma_B} \cdot \frac{2d_B}{d_B} = 4$$

$$\Rightarrow h_B = 4h_A = 0.04 \text{ m}$$

Multiple choice

18. The densities of acetone and water at 20°C are 0.792 g cm^{-3} and 0.9982 g cm^{-3} , respectively. The viscosity of water is $1.002 \times 10^{-3} \text{ Pa s}$ at 20°C . If at 20°C water

$$\eta = \frac{Adt}{l}$$

requires 120.5 s to run between the marks on a viscometer and acetone requires 40.5 s, what is the viscosity of acetone?

✓ A) $3.28 \times 10^{-4} \text{ Pa s}$

B) $2.90 \times 10^{-3} \text{ Pa s}$

C) $1.03 \times 10^{-3} \text{ Pa s}$

D) $3.06 \times 10^{-3} \text{ Pa s}$

E) $6.56 \times 10^{-4} \text{ Pa s}$

Ans: A

$$\frac{\eta_w}{\eta_A} = \frac{d_w t_w}{d_A t_A}$$

$$= \frac{0.9982}{0.972} \cdot \frac{120.5 \text{ s}}{40.5 \text{ s}} = 3.0555$$

$$\eta_A = \frac{\eta_w}{3.0555} = \frac{1.002 \cdot 10^{-3} \text{ Pa s}}{3.0555}$$

$$= 3.2793 \cdot 10^{-4} \text{ Pa s} = 3.28 \cdot 10^{-4} \text{ Pa s}$$

Multiple choice

19. Which of the following statements is not correct?

✓ A) The viscosities of gases decrease as temperature increases. incorrect

B) The viscosities of gases increase as temperature increases. $\eta \sim \sqrt{T}$ correct

C) The viscosities of liquids increase as temperature decreases. $\eta \sim e^{E_a/RT}$ correct

D) The viscosities of liquids obey a law of the Arrhenius type. see C)

E) For gases, viscosity is proportional to $T^{1/2}$, T being the temperature in Kelvin. see B)

Ans: A

Multiple choice

20. Water is transported upward in trees through channels in the trunk called xylem. Although the diameter of the xylem channels varies from species to species, a typical value is $2.0 \times 10^{-7} \text{ m}$. If the water surface tension and density are ~~$71.99 \times 10^{-4} \text{ N m}^{-1}$~~ and 997 kg m^{-3} , what will be the maximum transport height of the water to the top in the redwood tree?

A) 14 m

$$70.41 \cdot 10^{-3} \frac{\text{N}}{\text{m}}$$

maximum h at $\theta = 0^\circ$, $\cos \theta = 1$

B) 21.0 m

C) 45.9 m

D) 95.0 m

E) 214 m

Ans: A

$$h = \frac{28}{d \rho r \cos \theta}$$

$$h = \frac{2 \cdot 70 \cdot 10^{-8} \text{ N/m}}{997 \text{ kg/m}^3 \cdot 1.0 \cdot 10^{-7} \text{ m} \cdot 9.81 \frac{\text{m}}{\text{s}^2}}$$

$$= \frac{144.9}{143.97} \text{ m} = 144 \text{ m}$$

Multiple choice

21. The Galvanic cell $\text{Cu(s)} | \text{Cu}^{2+}(\text{aq}) || \text{Ag}^+(\text{aq}) | \text{Ag(s)}$ is based on the following cell reaction: $2\text{Ag}^+(\text{aq}) + \text{Cu(s)} \rightarrow 2\text{Ag(s)} + \text{Cu}^{2+}(\text{aq})$. Note that $T = 298 \text{ K}$ and the standard electrode potentials are $E^\circ(\text{Cu}^{2+}, \text{Cu}) = 0.34 \text{ V}$ and $E^\circ(\text{Ag}^+, \text{Ag}) = 0.80 \text{ V}$. Which of the following statements are correct?

~~cathode right, anode left~~

(i) The silver electrode is the cathode and the copper electrode is the anode. $E^\circ = E^\circ_{\text{right}} - E^\circ_{\text{left}} = E^\circ_{\text{Ag}^+/\text{Ag}} - E^\circ_{\text{Cu}^{2+}/\text{Cu}} = (0.80 - 0.34) \text{ V} = 0.46 \text{ V} > 0$
correct

(ii) Two moles of electrons flow through the external circuit from anode to cathode when the cell operates. e^- flow left to right
When $E > 0$, correct \Rightarrow reduction right for Ag^+/Ag
oxidation left for Cu^{2+}/Cu

(iii) The standard cell potential is 0.46 V.
correct

(iv) The change in Gibbs energy for the cell reaction is $-88,766 \text{ J mol}^{-1}$.
correct

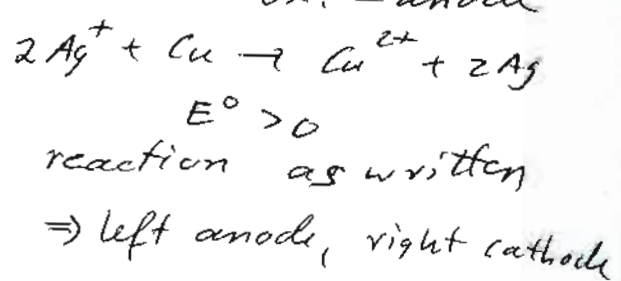
A) All statements are correct.

B) (i) only.

C) (i) and (ii) only.

D) (iii) and (iv) only.

E) None of the statements are correct.



Ans: A

$$\Delta G^\circ = -zE^\circ F = -2 \cdot 0.46 \text{ V} \cdot 96485 \frac{\text{As}}{\text{mol}}$$

$$= -88,766 \frac{\text{VA s}}{\text{mol}} = -88.766 \frac{\text{kJ}}{\text{mol}}$$

Multiple choice

$$E_{cell}^{\circ} = E_{right}^{\circ} - E_{left}^{\circ} = E_{Sn^{4+}/Sn^{2+}}^{\circ} - E_{Zn^{2+}/Zn}^{\circ}$$

22. Given the following Galvanic cell $Zn(s)|Zn^{2+}(aq)||Sn^{4+}(aq),Sn^{2+}(aq)|Pt(s)$. If the standard potential $E^{\circ}(Zn^{2+},Zn) = -0.76\text{ V}$ and the standard cell potential $E^{\circ}_{cell} = 0.91\text{ V}$, then the standard potential of the Sn^{4+}/Sn^{2+} redox couple is:

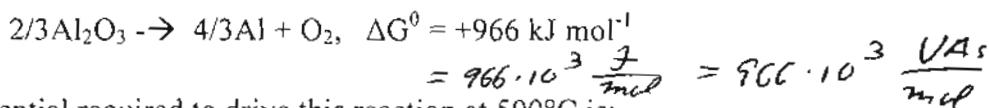
- ✓ A) 0.15 V $\Rightarrow 0.91\text{ V} = E_{Sn^{4+}/Sn^{2+}}^{\circ} + 0.76\text{ V}$
- B) -0.15 V
- C) 150 V
- D) 1.67 V
- E) -1.67 V

$$E_{Sn^{4+}/Sn^{2+}}^{\circ} = (0.91 - 0.76)\text{ V} = 0.15\text{ V}$$

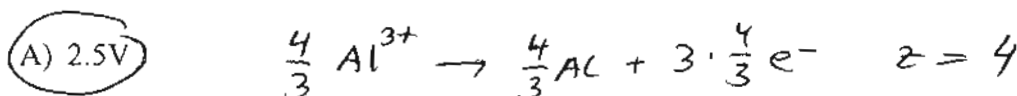
Ans: A

Multiple choice

23. The following reaction corresponds to electroextraction of aluminum from aluminum ore:



The minimum potential required to drive this reaction at 500°C is:



B) 5.0V

C) 4.5V

D) 3.0V

E) 1.2V

$$\Delta G^{\circ} = -z E^{\circ} F$$

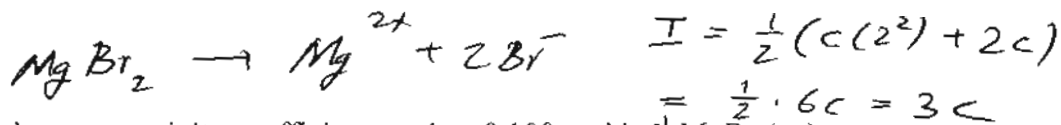
$$E^{\circ} = -\frac{\Delta G^{\circ}}{zF} = -\frac{966 \cdot 10^3 \frac{\text{VA s}}{\text{mol}}}{4 \cdot 96485 \frac{\text{As}}{\text{mol}}} = -2.50\text{ V}$$

$$= -2.50\text{ V}$$

Ans: A

\Rightarrow the reaction is non-spontaneous since $E^{\circ} < 0$

Multiple choice \Rightarrow at least 2.5V are needed to make it happen!



24. Given that the mean activity coefficient, γ_{\pm} , in a $0.100 \text{ mol kg}^{-1} \text{ MgBr}_2(\text{aq})$ solution is 0.524 at 25°C . Determine the percentage difference from the value predicted by the Debye-Hückel limiting law? $= 0.300 \text{ m}$

✓ A) 47%

B) 11%

C) 15%

D) 17%

E) 21%

Ans: A

$$\text{DHLL: } \lg \gamma_{\pm} = -0.5092 \cdot 12.11 \sqrt{0.3}$$

$$= -0.5578$$

$$\gamma_{\pm} = 10^{-0.5578} = 0.2768$$

$$\% \text{ diff} = \left| \frac{0.2768 - 0.524}{0.524} \right| \cdot 100\% = 47.18\%$$

$$= 47\%$$

Multiple choice

25. The solubility product of K_2SO_4 is (γ_{\pm} is the mean activity coefficient):

✓ A) $4S^3\gamma_{\pm}^3$

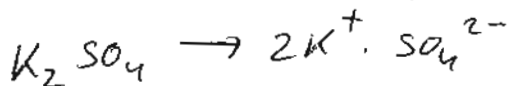
B) $4S^5\gamma_{\pm}^3$

C) $4S^3\gamma_{\pm}^2$

D) $4S^3\gamma_{\pm}^3$

E) $4S^2\gamma_{\pm}^3$

Ans: A



$$K_{sp} = a_{\text{K}^+}^2 a_{\text{SO}_4^{2-}}$$

$$= c_{\text{K}^+}^2 \gamma_{\pm}^2 \cdot c_{\text{SO}_4^{2-}} \gamma_{\pm}$$

$$c_{\text{K}^+} = 2s, \quad c_{\text{SO}_4^{2-}} = s$$

$$K_{sp} = (2s)^2 \gamma_{\pm}^2 \cdot s \gamma_{\pm}$$

$$= 4s^3 \gamma_{\pm}^3$$