Solution Test 1

Question 1

a. An aqueous solution of nitric acid (HNO_3) has a density of 1.42 g/mL and a mass percent is 70.0%. Calculate its molarity. (4 marks)

Use 1 L

$$1.00\,L \times \frac{1420\,g}{L} \times \frac{70.0}{100.} \times \frac{1\,mol\ HNO_3}{63.01\,g} = 15.77\ mole$$

therefore 15.8 mol/L

Answer: 15.8 M

. . . . . .

b. If 250.0 mL of 1.00 M K_2S(aq) is mixed with 1.00 L of 1.00 M $KHSO_4$(aq), what is the concentration of potassium ions, K^+(aq) in the final solution? (3 marks)

n_{K^+} from K_2S : $(0.2500\,L)(1.00\ mol/L\ K_2S)(2\,K^+/K_2S) = 0.500\ mol\ K^+$

n_{K^+} from $KHSO_4$: $(1.00\,L)(1.00\ mol/L\ KHSO_4) = 1.00\ mol\ K^+$

$$C = \frac{n}{V} = \frac{(0.500\ mol) + (1.00\ mol)}{1.00\,L + 0.2500\,L} = 1.20\ \frac{mol}{L}\ K^+$$

Answer: 1.20 M K^+

Question 2

a. A small maple syrup producer needs to evaporate some water from their daily production of 225 L of maple sap, c = 0.0555 mol·L^{-1} sucrose. Calculate the volume of water to be removed to obtain maple syrup with c = 2.0 mol·L^{-1} sucrose. (3 marks)

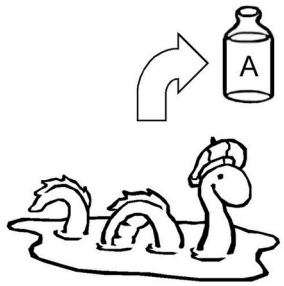
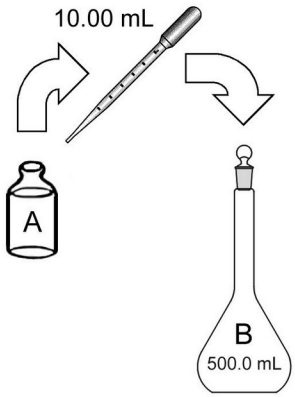
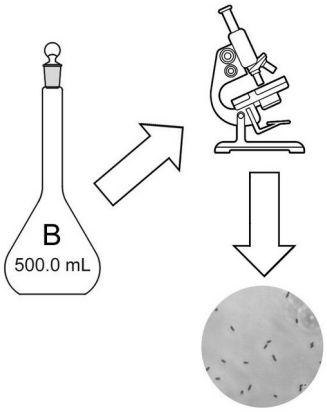
$n_{sucrose\ in\ production\ (sap)} = (225\ L)(0.0555\ \frac{mol}{L}) = 12.49\ mol$

Final volume (after evaporation) $c = \frac{n}{V} \Rightarrow V = \frac{n}{c} = \frac{12.49\ mol}{2.0\ mol/L} = 6.25\ L$

Volume water to evaporate = 225 L − 6.25 L = 219 L

Answer: 219 L

b. Consider the following water analysis:

1 - sampling	2- dilution	3- analysis
		
A water sample "A" is taken from a lake.	10.00 mL of this sample is diluted to 500.0 mL (solution B) with sterile water (no bacteria)	2900 bacteria were counted in a 5.0 mL sample of the solution "B"

Calculate the bacteria concentration in the lake? (bacteria/mL). (3 marks)

$$\frac{\frac{2900\ bac}{5.0\ mL} \times 500\ mL}{10.00\ mL} = 2.9 \times 10^4\ \frac{bacteria}{mL}$$

Answer: 2.9×10^4 bac/mL

Question 3

a. A 25.6 g sample of naphthalene, a covalent non-electrolyte compound, is dissolved in 300.0 g of toluene. If the freezing point of this solution is −98.6 °C, calculate the molar mass of naphthalene. The freezing point of toluene is −93.0 °C.

Note: You may need information from the data sheet to complete this problem (3 marks)

$\Delta T_f = i K_F m$ non-electrolyte : $i = 1$

$$m = \frac{\Delta T_f}{K_f} = \frac{-(-98.6\,^\circ C - (-93.0\,^\circ C))}{8.38\ ^\circ C/m} = 0.6683\ \frac{mol}{kg\ solvent}$$

$$\text{Molar mass} = \frac{mass}{mole} = \frac{25.6\,g}{(0.6683\ mol \cdot kg^{-1})(0.300\,g)} = 128\ g/mol$$

Answer: 128 g/mol

b. The van't Hoff factor is used to (circle one): (1 mark)

~~i)~~ calculate the solubility of salts in water

~~ii)~~ calculate the freezing point increase and the boiling point depression of a solution

iii) describes the number of particles into which a substance dissociates in solution

iv) all of the above are right

v) all the answers provided in this problem are wrong.

Question 4

a. At a specific concentration, the average rate of appearance of O_2 in the reaction: $2O_3(g) \rightarrow 3O_2(g)$ is 0.00250 M/s over the first 5.50 s. How many grams of ozone (O_3) will be consumed for each liter of gas in this time? (3 marks)

$$\frac{\Delta[O_3]}{2\Delta t} = \frac{\Delta[O_2]}{3\Delta t} \Rightarrow \frac{\Delta[O_3]}{\Delta t} = \frac{2}{3}\frac{\Delta[O_2]}{\Delta t}$$

$$\frac{\Delta[O_3]}{\Delta t} = \frac{2}{3}\left(2.50\times10^{-3}\ \frac{M}{s}\right) = 1.\bar{6}\times10^{-3}\ \frac{M}{s}$$

$$\text{Mass } O_3 \text{ consumed} = \left(1.\bar{6}\times10^{-3}\ \frac{M}{s}\right)(5.50\,s)\left(48.00\ \frac{g}{mol}\right) = 0.440\,g$$

Answer: 0.440 g

b. If, for a reaction, the concentration of reactants are measured in mol/L and the time in seconds, then the unit of the rate constant for a second-order reaction is (circle one): (1 mark)

$\frac{mol}{L.s}$ $\frac{1}{s}$ **$\frac{L}{mol.s}$** $\frac{mol.s}{L}$ $\frac{s.mol}{L}$ $\frac{mol^2}{L^2.s}$

Question 5

The following experimental data were obtained for the fluorination of ClO_2 at –23 °C, (4 marks)

$$F_2(g) + 2ClO_2(g) \longrightarrow 2FClO_2(g)$$

Exp.	$[F_2]$ (mol/L)	$[ClO_2]$ (mol/L)	Rate ($M.sec^{-1}$)
1	1.23	0.0050	0.0910
2	0.70	0.0100	0.0588
3	1.23	0.0100	0.182

a. Write a rate law that is consistent with those data (including the rate constant value with units)

$\frac{(3)}{(2)} = \frac{0.182\ M/s}{0.0588\ M/s} = \frac{k\,[1.23]^n[0.0100]^m}{k\,[0.70]^n[0.0100]^m}$

$\approx 3 = (1.76)^n\ (1)^m$

$n = 2$

$\frac{(3)}{(1)} = \frac{0.182\ M/s}{0.0910\ M/s} = \frac{k\,[1.23]^2[0.0100]^m}{k\,[1.23]^2[0.0050]^m}$

$2 = (1)^2\ (2)^m$

$m = 1$

Rate constant Based on (1): $0.0910\ M/s = k\,[1.23\ M]^2[0.0050\ M]^1$ ↳ solving for $k = 12.0\ M^{-2}s^{-1}$

rate law: $\text{rate} = 12.0\ M^{-2}s^{-1}[F_2]^2[ClO_2]$

b. Does the following proposed mechanism agree with the fluorination of ClO_2 reaction (part a)? (1 mark)

(step 1) $F_2 + ClO_2 \longrightarrow FClO_2 + F$ (slow)

(step 2) $F + ClO_2 \longrightarrow FClO_2$ (fast)

YES

or

NO

Explain: the rate law of the slow step is not the one of the reaction $\text{rate} = k[F_2][ClO_2]$

c. In question b, which of the two steps has the highest activation energy? (circle one.) (1 mark)

step 1 step 2

d. Assuming the proposed mechanism (b) is right, identify the intermediate compound (if any). (1 mark)

F_2 ClO_2 $FClO_2$ (F) no intermediate compound

e. Assuming the proposed mechanism (b) is right, identify the catalyst (if any). (1 mark)

F_2 ClO_2 $FClO_2$ F no catalyst

Question 6

a. In an acidic solution, sucrose (table sugar) can be broken down into its individual sugars: glucose and fructose. At 27 °C, it takes 54.5 minutes to convert half the sucrose to glucose and fructose, and at 37 °C, it takes 13.7 minutes. Estimate the activation energy, in kJ/mol, for the breakdown of sucrose.

Hint: since [sucrose] is the same is both experiments then k is directly proportional to the rate. (4 marks)

(1) $27\,^{\circ}C$ $T_1 = 300.\,K$ $k_1 = \frac{[Sucrose]}{54.5\,min}$

(2) $37\,^{\circ}C$ $T_2 = 310.\,K$ $k_2 = \frac{[Sucrose]}{13.7\,min}$

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

$$\ln \frac{\frac{[Sucrose]}{13.7\,min}}{\frac{[Sucrose]}{54.5\,min}} = \frac{-E_a}{8.314\,J/K.mol}\left(\frac{1}{310K} - \frac{1}{300K}\right)$$

$$1.381 = \frac{-E_a}{8.314\,J/K.mol}\left(-1.075\times10^{-4}\,K^{-1}\right)$$

$$E_a = 106790\,\frac{J}{mol}$$

Answer: 107 kJ/mol

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b. Which items correctly complete the following statement? (circle **TWO** correct answers): (2 marks)

A catalyst can act in a chemical reaction to:

i) increase the equilibrium constant.

ii) decrease the activation energy of the reaction.

iii) increase the %yield of the reaction

iv) decrease the enthalpy (ΔH) for the reaction.

v) provide a new pathway for the reaction.

vi) increase the activation energy of the reaction

Question 7

Assuming that the loss of ability to recall learned material is a first-order process with a half-life of 35 days. Calculate the number of days required to forget 90.0% of the material that you learned in preparation for this exam. (4 marks)

$$t_{1/2} = \frac{\ln 2}{k} \qquad k = \frac{0.6931}{35\ days} = 1.98 \times 10^{-2}\ day^{-1}$$

$$\ln [\ ]_t = \ln [\ ]_0 - k\,t$$

$$\ln [10.0\%] = \ln [100\%] - 1.98 \times 10^{-2}\ day^{-1}\,(t)$$

$$\frac{\ln (0.100)}{-1.98 \times 10^{-2}\ day^{-1}} = t = 116\ days$$

Answer: 116 *days*

Question 8

It takes about 2 hours for an average person to metabolize (or eliminate) the alcohol in 1 glass of wine or beer. Also, it takes 4 hours for the same person to process the alcohol from 2 drinks, 6 hours from three drinks and so on. What is the reaction order associated to the alcohol elimination mechanism in the human body? (No explanation required).

(1 mark)

☒ zero order ☐ first order ☐ second order

$$\text{rate} = \frac{[1\ \text{glass}]}{2\text{h}} = \frac{[1\ \text{glass}]}{2\text{h}} = \frac{[1\ \text{glass}]}{2\text{h}} = \text{constant},\quad \text{rate} = k$$