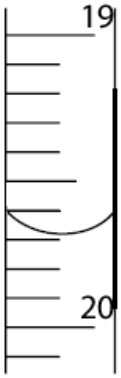
Analytical chemistry year 12

Name _____



1) Consider the image of the burette on the right.
   a) What is the volume reading of the burette on the Right?

19.68 mL

   b) What is the error of a burette reading?

+/- 0.02 mL

   c) Serotonin ($C_{10}H_{12}N_2O$; molar mass = 176 / mol) is a compound that conducts nerve impulses in the brain and muscles. A sample of spinal fluid from a volunteer in a study was found to contain a serotonin concentration of 1.70 ng/ L (1.70 nanograms per litre).
   How many molecules of serotonin are there in one millilitre of the spinal fluid?

$$1.7 \times 10^{-9}\ g$$

$$\frac{1.7 \times 10^{-9}}{176}\ mol$$

$$9.66 \times 10^{-12} \times 6.02 \times 10^{23}$$

$$\frac{5.8 \times 10^{12}}{10^{3}}$$

$$= 5.8 \times 10^{9}$$

   d) Xylose is a compound that has five carbon atoms in each molecule and contains 40% carbon by mass. What is the molar mass of xylose?

$$40\% \text{ of } x = 60$$

$$\Rightarrow \frac{40}{100} \times x = 60$$

$$\Rightarrow x = 150$$

1+1+2+2 =6 marks

2) An organic compound has the following percentage composition by mass. 49.79%C, 7.47%H, 13.28%O, 29.46% Cl.

a) Find its molecular formula if 1.50 mol of the substance weighs 180.0 grams

$$\frac{49.79}{12}\,C : \frac{7.47}{1}\,H : \frac{13.28}{16}\,O : \frac{29.46}{35.5}\,Cl$$

$$\Rightarrow 4.15 : 7.47 : 0.83 : 0.83$$

$$\Rightarrow 5 : 9 : 1 : 1$$

C_5H_9OCl Empirical formula

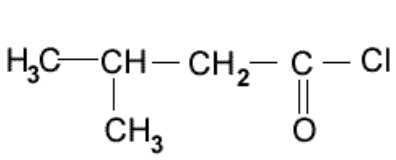
$$\frac{\text{Molecular mass}}{\text{Empirical mass}} = \frac{120}{120} = 1$$

C_5H_9OCl Molecular formula

2 marks

b) The NMR spectrum of the compound is shown on the right?

Draw a possible structure for this compound.



2 marks

3) 0.4415 g of a pure acid, $H_2X(s)$, is added to exactly 80.0 mL of 0.105 M NaOH(aq).
A reaction occurs according to the equation
$H_2X(s) + 2NaOH(aq) \rightarrow Na_2X(aq) + 2H_2O(l)$
The NaOH is in excess. This excess NaOH requires 25.21 mL of 0.197 M HCl(aq) for neutralisation.
Calculate
i. the amount, in mol, of NaOH that is added to the acid H_2X initially.

$$n = C \times V$$
$$= 0.105 \times 0.0800$$
$$= 0.0084 \text{ mol}$$

ii) the amount, in mol, of NaOH that reacts with the acid H_2X

$$n = C \times V$$
$$= 0.197 \times 0.02521$$
$$= 0.00495 \text{ mol remaining}$$

$$\text{Mol reacted} = 0.0084 - 0.00495$$
$$= 0.00345$$

iii) the molar mass, in g mol^{-1}, of the acid H_2X.

$$\text{mol of acid} = 0.001725$$

$$M = \frac{m}{n}$$
$$M = \frac{0.4415}{0.001725} = 255.94$$

4) The amount of iron in a newly developed, heat-resistant aluminium alloy is to be determined.
An 90.50 g sample of alloy is dissolved in concentrated hydrochloric acid and the iron atoms are converted to $Fe^{2+}(aq)$ ions.
This solution is accurately transferred to a 500.0 mL volumetric flask and made up to the mark.
25.00 mL aliquots of this solution are then titrated against a standard 0.0450 M potassium permanganate solution.

$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$

Four titrations were carried out and the volumes of potassium permanganate solution used were recorded in the table below.

Titration number	1	2	3	4
Volume of $KMnO_4$ (mL)	20.02	19.98	21.23	20.01

a) Write a balanced half-equation, including states, for the conversion of $MnO4^-$ ions, in an acidic solution, to Mn^{2+} ions

2 marks

$MnO_4^-{}_{(aq)} + 8H^+{}_{(aq)} + 5e \Rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$

b) Calculate the average volume, in mL, of the concordant titres of the potassium permanganate solution

(20.02 + 19.98 + 20.01)/3 =20.00

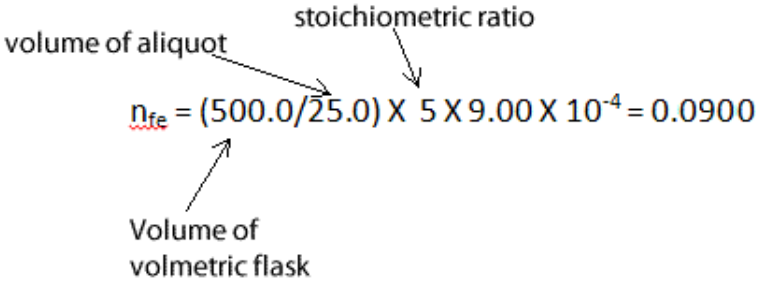
1 mark

c) Use your answer to part b. to calculate the amount, in mol, of MnO_4^- (aq) ions used in this titration

n = C X V
=> n = 0.045 X 0.02 =9.00 X 10^{-4}

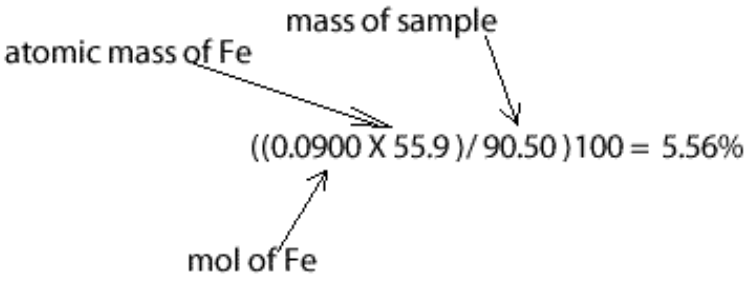
1 mark

d) Calculate the amount, in mol, of $Fe^{2+}(aq)$ ions present in the 500.0 mL volumetric flask.



2 marks

e) Calculate the percentage, by mass, of iron in the 90.50 g sample of alloy. Express your answer to the correct number of significant figures.



3 marks

5) When substance "X" with empirical formula CH_2O is dissolved in water it reacts to form a mixture with substance "Y" with empirical formula CH_3O according to the equation below
$X(aq) + H_2O(l) \Rightarrow Y(aq)$
The concentration of "X" can be determined using UV-visible spectroscopy. "X" absorbs strongly at 290 nm while "Y" shows no absorption at this wavelength.
In a particular experimental arrangement at 25°C, the relationship between absorbance at 290 nm and concentration of "X" is given by the relationship
Absorbance = 7.15 x ["X"]
In the experiment, 0.0550 mol of "X" is dissolved rapidly in 0.500 L of water at 25°C. The absorbance of the solution changes as some of the "X" is converted to "Y". The table below shows the change in absorbance over

Absorbance	0.530	0.430	0.320	0.285	0.280	0.280
Time (s)	6.00	60.0	90.0	120	240	480

a) Calculate the concentration of "X", in M, when the reaction was complete.
["X"] = 0.280/7.15 = 0.0392 M

2 marks

b) Calculate the absorbance at the instant that "X" was dissolved in the water, before any reaction occurred.
Absorbance = 7.15 X 0.110 = 0 .787

1 mark

c) Calculate the percentage of the original 0.0550 mol of "X" that has been converted into "Y" at the end of the reaction
Step 1 Calculate the amount of "X" remaining
$n_{"X"}$ = C X V = 0.0392 X 0.500 = 0.0196
Step 2 Calculate amount used up 0.0550 – 0.0196 = 0.0354
Step 3 Find the percentage used (0.0354/0.0550) X 100 = 64.4%

2 marks

d) The average rate of a reaction can be determined by calculating the change in concentration of a reactant per second. Calculate the average rate, in M/s–, at which the concentration of "X" changed during the first 6.00 s of the reaction.

Step 1 Find the ["X"] at 6 seconds. ["X"] = 0.530/7.15 = 0.0741 M

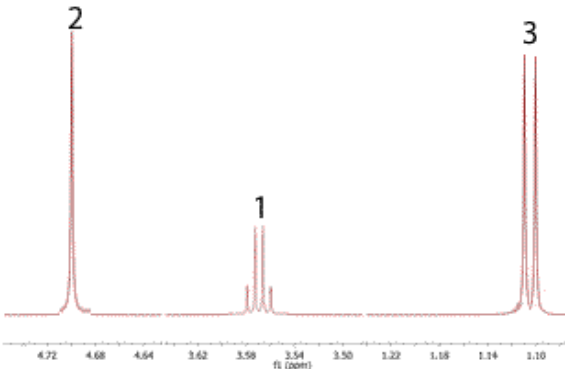
Step 2 Calculate the decrease in ["X"]

=> $\triangle$ ["X"] = 0.110 – 0.0741 = 0.0359

Step 3 Calculate the rate 0.0359/6.00 = 0.00598M/s

2 marks

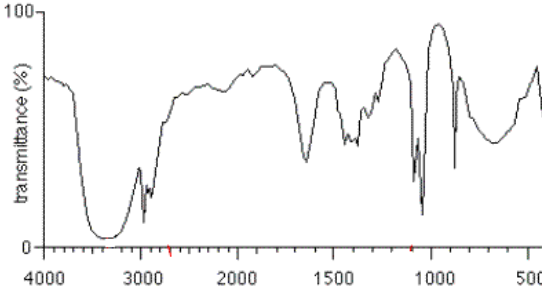
e) The formula mass of "Y" is 62. Consider the NMR and IR spectra given on the right.



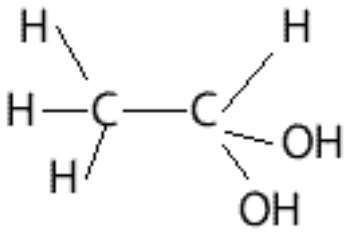
i) What type of bonds are present, as indicated by the IR spectrum of "Y" between 3,000 and 3,300.

O-H, C-H

2 marks



ii) Draw a possible structural formula for "Y"



Atomic absorbtion, IR spectroscopy, NMR spectroscopy, Mass spectroscopy HPLC

6) a) A piece of shark meat was analysed for mercury content. Which of the analytical techniques above is most appropriate for this analysis?
Atomic absorption

1 mark

c) Which two techniques above can be used to determine the structure of an organic compound?
IR, NMR and Mass spectrometry

2 marks

d) Which technique can be used to separate a mixture of proteins into its component proteins?
HPLC

1 mark

e) A mixture of butane, ethanol and 1,2-ethandiol is to be separated by column chromatography technique which uses a silicon based stationary phase covered in OH groups. The mobile phase is carbon tetrachloride.
i) Which substance will have the highest retention time? Explain why
1,2-ethandiol. It is the most polar molecule and hence will adsorb strongly to the stationary phase and interact less with the non-polar mobile phase.

2 marks

ii) Place the three substances in order of increasing retention time?

_____*butane*

_____*ethanol*

_____*1,2-ethandiol*

3 marks

f) Which two techniques would not be used to identify an organic molecule of which a very small sample is available and must be preserved for further testing? Explain why

Atomic absorption and mass spectrometry

Atomic absorption cannot be used with organic molecules while mass spectrometry is a destructive method and will use up the minute quantities of sample.

3 marks

g) In which technique is the sample vapourised in the presence of a strong reductant.

Atomic absorption

1 Mark

7) The level of carbon dioxide in the air in a spacecraft can be controlled by passing the air through canisters containing lithium hydroxide, LiOH.
In a laboratory trial, the air in a 2.50 L container at 1.10×10^2 kPa and 20.0°C was passed through a canister of LiOH. The pressure of the air in the container decreased to 0.90×10^2 kPa, measured at 20.0°C.
Calculate the mass of CO_2 absorbed from the air sample by the LiOH in the canister.

$PV = nRT$

The reduction in pressure is due to the removal of carbon dioxide.
20.0 kpa is due to the carbon dioxide partial pressure.
Volume = 2.50 L
Temperature = 293 K

$$n = \frac{PV}{RT} = \frac{20.0 \times 2.5}{8.31 \times 293} = 0.0205$$

mass = n X M = 0.0205 X 44.0 = 0.902 g