**Solution Pathway**

*Note: Teachers will need to provide the VCAA data booklet, unmarked, for student use during this Exam.*

**SECTION A: Multiple Choice Answers**

**Question 1 Answer: D**

From the Data book, the acidity constants indicate

HF $K_a = 7.6 \times 10^{-4}$

$HNO_2$ $K_a = 7.2 \times 10^{-4}$

HCN $K_a = 6.3 \times 10^{-10}$

HCl is a strong acid and will have the greatest number of conjugate ions present. HCN will have the least number of conjugate ions present.

**Question 2 Answer: D**

The key point is the same amount of mole of each acid is required to react with NaOH, the base.

$H_2SO_4$ is diprotic; therefor requiring double the volume of NaOH.

$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$ Double the amount of NaOH required.

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H2O(l)$

$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COO^-Na^+(aq) + H_2O(l)$

CH3COOH is a weak acid. HCl and H2SO4 are strong acids. This is not the key factor.

**Question 3 Answer: B**

A. $CH_4$, $\mathbf{C_2H_6}$, $C_6H_5CH_3$, $CH_3COOH$

B. $HNO_3$, $Fe_2(SO_4)_3$, $C_6H_5CH_3$ $CH_3Cl$

C. $CH_3OH$, $C_2H_6O$, $CuSO_4.5H_2O$, $\mathbf{C_6H_{12}O_6}$

D. $\mathbf{C_4H_8}$, $CCl_4$, $Mg(OH)_2$, $K_2Cr_2O_7$

Formulas in bold are not in there simplest ration.

**Question 4 Answer: A**

$NH_4SO_4$

%(N) = 14/(14 + 4 +32.1+64) x 100 = **12.3%**

$NH_4NO_3$

%(N) = (2 x 14)/( 28 +4 + 48) x 100% = 35.0%

$(NH_4)_3PO_4$

%(N) = (3 x 14)/ (42 + 12 + 19 + 64) x 100% = 30.7%

$(NH_2)_2CO$

%(N) = (2 x 14)/(28 + 4 + 12 + 16) x 100% = 47.7%

**Question 5 Answer: C**

I Mole

n(Cl2) = m/M = 21.1/71.0 = 0.297mol

11 %w/v

%(w/V) = 21.1/ 9000 x 100% w/v =0.234%

III density

density = m/v = 21.1/9.00 = 2.34 $gL^{-1}$

**Question 6 Answer: C**

A. 3.00 mol

3.00/2 x 3120 = $4.680 \times 10^3$ kJ

B. 100 g

100/ (2x12+6x1) = 3.333mol

3.333/2 x 3120 = $5.199 \times 10^3$kJ

C. 10.0L at SLC

10.0/24.5 =0.408 mol

0.408/2 x 3120 mol = $6.367 \times 10^{2}$kJ

D. $2.408 \times 10^{23}$ atoms

$2.408 \times 10^{23}$/ $6.02 \times 10^{23}$ = 0.4 mol

0.4 x 3120/2 = $6.240 \times 10^2$ mol

**Question 7 Answer: D**

Flame test will identify the presence of sodium but not the concentration of sodium chloride

High Performance Liquid Chromatography will not detect the presence of sodium chloride. HPLC is used for the detection of complex organic substances, NaCl is inorganic.

**Question 8 Answer: B**

Both I and IV would lead to an underestimate, whilst II and III would lead to an overestimate in the actual mass of sodium chloride. Not weighing to constant mass, would mean the presence of moisture could still be in the sample, not rinsing with a small volume of deionised water could mean the presences of impurities adsorbed onto the surface of the precipitate.

**Question 9 Answer: C**

The overall equation for the reaction when a battery recharges is:

$2PbSO_4(s) + 2H_2O(l) \rightarrow Pb(s) + PbO_2(s) + 2SO_4^{2-}(aq) + 4H^+(aq)$

pH of the electrolyte is decreasing as the cell recharges.

**Question10 Answer: D**

A catalyst lowers the activation energy without altering the enthalpy of a reaction.

**Question 11 Answer: D**

$C_1V_1 = C_2V_2$

$2.00 \times V_1 = 0.01 \times 200$

$V_1 = 1$ mL

**Question 12 Answer: A**

The final rinsing must be with the solution to be transferred in the pipette. Using distilled water instead of sodium carbonate solution will dilute the standard sodium carbonate. The volume of HCl required will be less. This will lead to an underestimate in the concentration of HCl.

**Question 13 Answer: C**

The concentration of $Na^+$ = the concentration of $Na_2CO_3$ in 100mL

$= 2 \times 0.0500 = 0.100 \text{ mol L}^{-1}$

$= 0.100 \times 23 \text{ g L}^{-1}$

$= 2.3 \text{ g L}^{-1}$

**Question 14 Answer: A**

Zinc oxide is reduced to zinc by carbon monoxide, therefore carbon monoxide is the reductant.

**Question 15 Answer: B**

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ Reduction of copper ion to copper solid is also found in the data book.

**Question 16 Answer: D**

The overall equation is

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

**Question 17 Answer: C**

$R_f$ of component B is calculated from the ratio of comparison of distances moved and the $R_f$ of component A: $R_f$ of component B = $\frac{3 x 0.5}{2}$ = 0.75

**Question 18 Answer: B**

Nitrogen is an inert gas and will not react with the compounds. The lower the boiling point indicates a lower molecular mass and therefore a shorter retention time.

With an increase in temperature, molecules will move faster and thus will reduce the retention time.

**Question 19 Answer: D**

NMR uses energy in the radio frequency which is too low to cause electromagnetic vibration or rotational spins. NMR uses an external magnetic field, and the spinning nucleon of $H^1$ to identity the chemical environment of the Hydrogen-1 nucleon.

**Question 20 Answer: B**

Gas chromatography would be used as 1,2-diethanol is a small volatile molecule and can be quantitatively analysed. Mass spectrometry would determine the structure and identity of 1,2-diethanol.

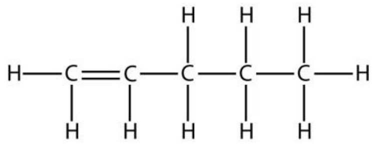
**Question 21 Answer: C**

Naming the compound firstly the longest continuous chain of carbon atoms must be identified.

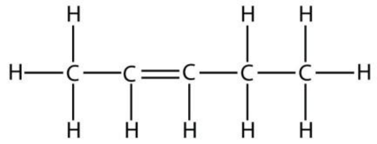
**Question 22 Answer: B**

Structural isomers refer to compounds that have the same molecular formula but different structural formulae.

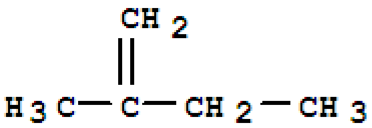
Possibilities for $C_5H_{10}$ are



1-Pentene

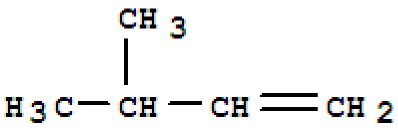


2-Pentene



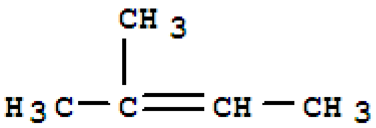
$$H_3C-\overset{\overset{CH_2}{\|}}{C}-CH_2-CH_3$$

2-methyl-1-butene



$$H_3C-\overset{\overset{CH_3}{|}}{CH}-CH=CH_2$$

3-methyl-1-butene



$$H_3C-\overset{\overset{CH_3}{|}}{C}=CH-CH_3$$

2-methyl-2-butene

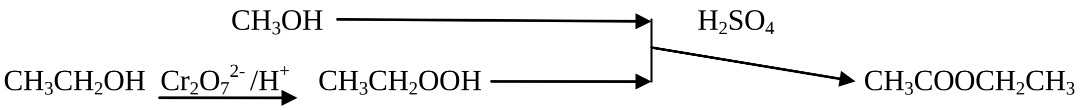
**Question 23 Answer: D**

$H_2NC_3H_6COOH$ has both a basic - $NH_2$ amine functional group and an acidic-COOH carboxyl functional group allowing it to react with both a dilute acid, $HNO_3$ or a dilute base, NaOH.

**Question 24 Answer: C**

The alcohol forms the prefix of an ester, with the acid following. –ate refers to the ester.

**Question 25 Answer: A**



**Question 26 Answer: D**

Using the Data Book:

Methanol = (725/32) = 22.7 kJ/g

Ethene = (1409/.28) = 50.3 kJ/g

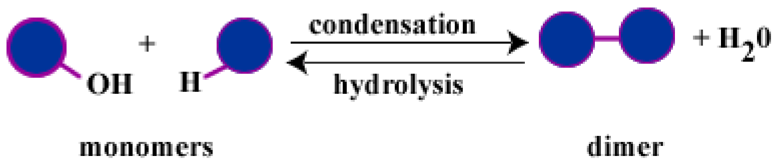
Methane = (889/16) = 55.6 kJ/g

Hydrogen = (286/2) = 143 kJ/g

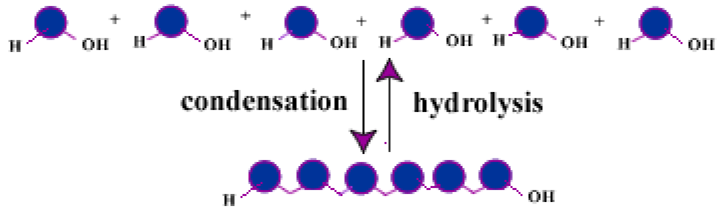
**Question 27 Answer: C**

Hydrolysis of starch involves breaking the bonds between the glucose molecules with the addition of water to do so.

(1) Dimer



(2) Polymerisation



http://click4biology.info/c4b/3/chem3.2.htm

**Question 28 Answer: D**

The phosphate group on the backbone of the DNA molecule causes DNA to have an overall negative charge. There it will begin from the negative terminal, connected at W and move towards the positive terminal. Fragment S will have a higher molecular mass than fragment and will thus move at a slower rate through the gel than fragment T from where the samples are loaded.

**Question 29 Answer: C**

Using the data book, the R groups of the amino acids can be compared. Leucine would be the least soluble at pH 7 as the R group consists of only hydrocarbons, being non-polar and would reduce its solubility in an aqueous solution. Each of the other amino acids contains a polar group.

**Question 30 Answer: B**

The three hydrogen's of $CH_3COO^-$ appear as the tallest peak as they are all in the same environment and appear as a singlet without another neighbouring H environment.(n + 1 rule = 1).

## SECTION B

### Question 1

**a.** 25˚C or 298K

1 atm pressure

1M concentration of solutions (3)

**b.** pH = $-\log_{10}[H^+]$ = $-\log_{10}[1]$ = pH = 0 (2)

5 marks

### Question 2

**a.** Hydrogen peroxide can act both as a reductant and an oxidant. Write the equation when hydrogen peroxide is acting as an oxidant. Include all states and the EMF (V)

$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$; E˚ = 1.77 V (1)

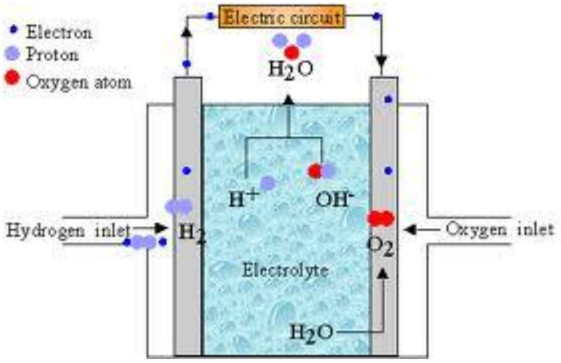
**b.** Cell Potential Difference = higher half-cell E˚ - lower half-cell E˚ of the electrochemical series.

1.77 – (+0.68) = 1.09 V (1)

**c.** The rate of reaction is too slow; the electrochemical series does not give information about the rate of a reaction. (1)

3 marks

### Question 3



http://www.cheng.cam.ac.uk/research/groups/electrochem/JAVA/electrochemistry/ELEC/l10html/main.html

**a.** Cell is as galvanic cell. (1)

**b.** $O_2(g) + 2H_2O(1) + 4e^- \rightarrow 4OH^-(aq)$ (1)

**c.** $H_2(g) + 2\,OH^-(aq) \rightarrow 2H_2O(1) + 2e^-$ (1)

**d.** Provides a greater surface to act as a catalyst between the gases, hydrogen and oxygen at each electrode and to allow the transfer of ions produced in the half reactions. The electrolyte increases the rate of reaction. (1)

**e.** A fuel cell needs a constant injection of reactants, where as a primary cell has a set amount of reactants to use. (1)

**f.** One of:

Chemical energy of methanol is converted directly to electrical energy and is therefore more efficient than fossil fuel conversions to electrical energy. OR

The fuel cell will generate electricity as long as there is a constant source of methanol. OR

It is readily available at consistent quality as a mass-produced commodity, and in cost-per-unit-of-energy terms compares favourably with petrol and diesel. OR

Methanol is a convenient liquid fuel, easily handled and easily transported, less risk of explosion as with hydrogen gas, eliminating many of the difficulties associated with the provision of compressed gases such as hydrogen where infrastructure is lacking. OR

Methanol can be produced from feedstock such as biomass and waste, in line with the principles of Green Chemistry, reduce, re-use, and recycle. (1)

**g.** One of (or any reasonable specific statement):

Carbon dioxide is still a product emitted when methanol is used, a greenhouse gas would still be released into the atmosphere. OR

Methanol is still be a non-renewable fossil fuel (unless it is produced as a synthesis gas eg from carbon monoxide and hydrogen) and is not sustainable for large volume production of electricity. OR

Fuels cells generate a direct current, so an inverter is required to change DC to AC at the appropriate voltage. (1) 7 marks

**Question 4**

**a.** Energy (J) = mass (g) x S.H.C x $\Delta$t (℃ )

| Methanol | Ethanol | Propanol |
|---|---|---|
| = 100.0 x 4.18 x 58.2 | = 100.0x 4.18 x 56.7 | = 100.0 x 4.18 x 45.5 |
| = 24327.6J | = 23700.6J | = 19019.0J |

(3)

**b.** Methanol Ethanol Propanol

n(methanol) = $\frac{1.59}{32}$ =0.0497mol

n(ethanol) = $\frac{1.82}{46}$ =0.0396mol

n(propanol) = $\frac{1.37}{60}$ =0.0228mol

(3)

$\Delta H$ = q/1000 /n $= \frac{24327.6}{1000x0.0497}$ = -489kJmol$^{-1}$

$\Delta H$ = q/1000 /n $= \frac{23700.6}{1000\ x0.0396}$ = -599kJmol$^{-1}$

$\Delta H$ = q/1000 /n $= \frac{19019.0}{1000x0.0228}$ = -833kJmol$^{-1}$

(2)

**c.**

| **Alkanol** | **Experimental data (kJmol$^{-1}$)** | **Data book$\Delta Hc$ (kJmol$^{-1}$)** |
|---|---|---|
| Methanol | -489 | -725 |
| Ethanol | -599 | -1364 |
| Propan-1-ol | -833 | -2016 |

(1)

The experimental results are consistently less than the expected value for the molar enthalpy of each fuel. (1)

The greater the molar mass of the fuel, the more energy there is available (kJ) per mole of fuel. (1)

**d.** $C_3H_8O(l) + 4.5\ O_2(g) = 3CO_2(g) + 4H_2O(l)\quad \Delta H = -146kJmol^{-1}$

Or

$2C_3H_8O(l) + 9\ O_2(g) = 6CO_2(g) + 8H_2O(l)\quad \Delta H = -292kJmol^{-1}$

(2)

**e.** Any 2 of the following or any error that relate directly to the technique of calorimetry.

- The method is very inaccurate because a huge loss of radiant heat energy from the combustion reaction is absorbed by the surrounding air surrounding the flame and not the water.
- The combustion of each fuel is carried out in air and not pure oxygen. This would lead some of the fuel undergoing incomplete combustion, supported by the observation of soot on the bottom of the calorimeter. (The nitrogen in the air would also absorb some of the heat energy).
- There is evaporation of some of the alkanol from the wick of the spirit burner.
- The flame may not have been concentrated at the same point due to draughts.
- There was no stirring of the water, leading to an uneven distribution of the heat.

(2)

**f.** The same burner and set up, including the volume of water would have been used for each fuel.

(1)

**g.** $NH_4Cl(s) + H_2O(l) \rightarrow NH_4^+(aq) + Cl^-(aq)$ $\Delta H$ is + positive kJ $mol^{-1}$

(2)

**h.** Any one of:

- The density of the aqueous solution is assumed to be the same as that for water ie 1g/Ml.
- Adding the solid ammonium chloride has not changed the overall volume.
- The specific heat capacity of the ammonium chloride solution is the same as water i.e. 4.18 J $g^{-1}K^{-1}$

(1)

20 marks

**Question 5**

**Nicholas** would **only** be correct if the temperature of the neutral solution was at 298 K or $25^0$C.(1) In an aqueous solution, $H_3O^+$ ions and $OH^-$ ions are always present from the self- ionisation of water.

$$H_2O(l) + H_2O(l) \leftrightarrow H_3O^+(aq) + OH^-(aq)$$

A neutral solution is where the $[H_3O^+] = [OH^-]$ and this only happens at 25℃. (1)

As the temperature changes from 25℃ , $[H_3O^+]$ is not equal to $[OH^-]$, consequently the pH will not equal 7. (1)

**David** said that a neutral solution was when $[H_3O^+] = [OH^-]$. This is true irrespective of temperature(1). But he is incorrect in saying the pH would equal 7.(1)

**Jack** was not correct because pH =7 for a neutral solution is true only at 298 K or 25℃. (1)

6 marks

**Question 6**

**a.** $Mg(OH)_2(s) + 2\ HCL(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$

(1)

**b**. According to the Data Book, the end-point would need to near pH 7, thus phenol red or bromothymol blue. Either answer is acceptable.

(1)

**c**. n(HCl) = c xV = 3.30 x 25.6 x $10^{-3}$ = 0.08448 mol = 0.0845 mol (3 sig fig.)

(1)

**d.**

n(HCl) = n(NaOH) = c x V = 0.0740 x 27.4 x $10^{-3}$ = 0.00203mol = 2.03 x $10^{-3}$mol

(1)

**e.**

n(HCl) reacted = n(HCl)initially added – n(HCl) remaining that reacted with NaOH

=0.0448 – 0.0020276 (values left on calculator)

=0.0824524

=0.0825mol (1+ 1 sig. fig) (1)

**f.**

$n(Mg(OH)_2)$ = n(HCl) x ½ (mole ratio) (1)

= 0.0824524/2

= 0.0412262 mol

$m(Mg(OH)_2$ in one tablet (mg) = n x M /2tablets

=0.412262 x (24.3+ 2x16.0 + 2x 1.0)/2

= 1.20 g (1)

%(m/m) = (1.20 / 1.70) x 100%

=70.1% (1)

(3)

**g.** A bubble was present below the tap of the burette meant that the volume of NaOH used was actually less than read off the burette. Therefor the mole of NaOH and the mole of HCL would be falsely higher than the actual amount (1). Thus the amount of HCl reacting with the $Mg(OH)_2$ would have been less than the real amount . This would lead to a calculated value of Magnesium Hydroxide being lower than the actual value (1): an underestimate. (2)

**h**.It was necessary to perform a back titration of magnesium hydroxide as magnesium hydroxide has low solubility in water.

(1)

11 marks

**Question 7**

**a.**

$K = [NO_2]^2 / [N_2O_4]$ M

Or
$0.0510 = [NO_2]^2 / [N_2O_4]$ M

(1)

**b.** $K = [NO_2]^2 / [N_2O_4]$ M

$0.0510 = [NO_2]^2 / [N_2O_4]$

$[NO_2]^2 = 0.0510 \times [N_2O_4]$

$[N_2O_4] = n/V$
$=(10.0/(2\times14.0 + 4 \times16.0))/5.00$
$=0.108/5$
$=0.0217 \text{mol L}^{-1}$ (1)

$[NO_2]^2 = 0.0510 \times 0.0217 = 0.0011$
$[NO_2] = \sqrt{0.0011}$
$=0.0333 \text{ mol L}^{-1}$ (1)

$n(NO_2) = c \times V$
$=0.0333 \times 5$
$=0.166$ mol (1)
$m(NO_2) = n \times M$
$= 0.166 \times (14.0 + 2 \times 16)$
= 7.66g(3 sig figs) (1 + 1 sig figs) (6)

**c.** As the temperature is increased the colour of the mixture would have an increasing darker brown intensity and will remain the same intensity of brown. (1)

This can be explained according to Le Chatelier's principle. The forward reaction is endothermic. (1) According to Le Chatelier's principle an increase in temperature will favour the forward reaction, the endothermic direction in order to partially oppose the change. As $NO_2$ is brown the brown colour intensity will increase then remain constant when the new equilibrium is reached. (1)

10 marks

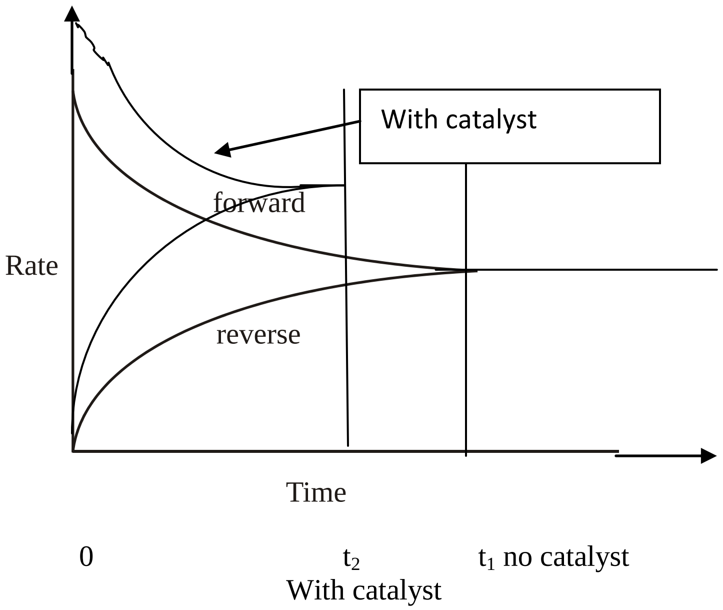
**Question 8**

Sulphur dioxide and Nitrogen dioxide were admitted to an empty vessel then sealed and allowed to reach equilibrium at temperature X°C, and time, *t* secs.

The equation for the reaction is

$NO_2(g) + SO_2(g) \leftrightarrow NO(g) + SO_3(g)$

**a.** Use the axes below to sketch a graph of the rates of the forward and back reactions against time, starting at t = 0, t = equilibrium and after equilibrium has been established. Label the axis, the forward and reverse reaction, indicate the time where equilibrium is established



Two curves – one labeled ‘forward’ starting up high up y-axis and one labeled ‘reverse’.

Starting from zero; curves merge and become horizontal; (1)

*forward reaction:*

highest concentration, thus rate high to begin with;
as reaction proceeds, concentrations decrease, so does rate (1).

*reverse reaction:*

zero rate initially/at t = 0 (since no products present); (1)
rate increases as concentration of products increases;
equilibrium established when rate of forward reaction = rate of reverse reaction;line is horizontal.

t1 is labelled as initial equilibrium (1).

**b.** Equilibrium is reached at an earlier time, t2 (1). The forward reaction occurs at a greater rate and the back commences and continues at a greater rate (1).

**c.** A catalyst speeds up both the forward and the reverse reaction, at the same rate. The equilibrium may be reached sooner but a catalyst does not alter the position of the equilibrium (1). The catalyst provides and alternative pathway for the reaction that has a lower activation energy (1).

**d.** As the temperature is increased, particles move faster. The reactants have more kinetic energy (1) and thus there are more successful or fruitful collisions per unit of time (1).

10 marks

**Question 9**

**a.** $Pb^{2+}(aq) + SO_4^{2-}(aq) = PbSO_4(s)$ (1)

**b.** The filtered precipitate was rinsed with deionised water. It was dried in an oven at 96℃. Over 5 days the following weighing's were recorded.

| Sample of Lead precipitate | Mass (g) |
|---|---|
| 1 | 0.4732 |
| 2 | 0.4616 |
| 3 | 0.4612 |
| 4 | 0.4613 |
| 5 | 0.4620 |

Calculate the mass (g) of the lead in the precipitate. Select values with the least range.

Average mass of the $PbSO_4(s)$ = (0.4616 + 0.0.4612 +0.4613)/3

= 0.4614g (1)

$n(PbSO_4)$ = m/M

=0.4614/(207.2+32.1+4x16.0)

= 0.001521mol

= $1.521 \times 10^{-3}$ mol (1)

$m(Pb^{2+})$ = n x M

= 0.001521 x 207.2

=0.3152g (1)

**c.** $n(Pb^{2+})$ = n $(PbSO_4)$ = $1.521 \times 10^{-3}$ mol

c $(Pb^{2+})$ = n/V

= $1.521 \times 10^{-3}$ mol/0.250

= $6.085 \times 10^{-3}$ mol $L^{-1}$ (1)

d. c $(Pb^{2+})$ = $6.085 \times 10^{-3}$ mol $L^{-1}$

m $(Pb^{2+})$ = n x M /L

=$6.085 \times 10^{-3}$ x 207.2

=1.261g$L^{-1}$

=$1.26 \times 10^{3}$mg$L^{-1}$ (1)

**d.** The maximum level of lead in safe drinking water is 0.015ppm = 0.015mgL$^{-1}$ . The polluted water well above and unfit for human consumption. (1)

**e.** The result would add to the mass of the precipitate and result in an over-estimate of the true mass of the Pb$^{2+}$ content. (1 )

**f.** $Pb^{2+}(aq) + SO_4^{2-}(aq) = PbSO_4(s)$

$n(Na_2SO_4) = n(PbSO_4)$
$= 1.521 \times 10^{-3}$ mol (1)
$V(Na_2SO_4) = n/c$
$=1.521 \times 10^{-3}/0.2$
$=7.65$mL (1)

**g.** The precipitating agent should be in excess to ensure complete precipitation of all the Pb$^{2+}$ ions. (1)

10 marks

**Question 10**

**a.** The wavelength from the lamp must match the wavelength to be absorbed by the metal calcium (1).

**b.** The aspirator burner evaporates water from the sample and the calcium ions are reduced to a vapour of atoms (1). The electrons from the calcium atoms absorb radiation coming from the hollow cathode lamp (1). (The amount of absorbance is measure by the detector).

**c.** Line of best should be drawn, with the calcium concentration(mgL$^{-1}$) on the X-axis and absorbance on the y-axis. (2 marks for graph labelled correctly)

From the graph the calcium concentration will read 2.8 mgL$^{-1}$ (+/- 0.1) in the diluted milk sample (1).

**d.** The total dissolved calcium, mgL$^{-1}$
$2.8 \times 100/1 \times 10/2$ (1)
=1400mgL$^{-1}$
$=1.4 \times 10^3$ mg L$^{-1}$ 2 sig figs (1)

**e.** Calculate the percentage, ( m/v) of calcium in the milk sample
$1.4 \times 10^3$ mg L$^{-1}$
=1.4g L$^{-1}$
=0.14% (m/v) (1)

**f.** There must have been calcium ions in the blank solution and the AAS spectrophotometer was not correctly calibrated to zero absorbance prior to running the samples (1).

**g.** A calcium cathode lamp emits a specific wavelength of light that can only be absorbed by other calcium atoms or ions. Hence sodium ions do not interfere (1). 12 marks

## Question 11

**a.** $CH_2OH^+$ the fragment must have the plus charge included. (1)
**b.** Molecular mass = 60 g $mol^{-1}$ (1)
**c.** $C_3H_8O$ (1)
**d.** $CH_3CH_2^+ \rightarrow CH_3^+ + \bullet C H_2$ (1)
**e.** The bond is C=O Wave number ($cm^{-1}$)range is1670 – 1750 (2 )

6 marks