This section contains 30 multiple choice questions.
For each question choose the response that is correct or that best answers the question.
Indicate your answer **on the answer sheet provided**.
Choose only **one** answer for each question.
A correct answer scores 1, an incorrect answer scores 0. Marks will **not** be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Question 1

The amount of ions, in mol, in 200 mL of an aqueous solution of 0.40 M potassium fluoride would be

A.   0.040

B.   0.080

C.   0.160

D.   0.200

[handwritten: $C = \frac{n}{V}$ $n = CV$
$= 0.4 \times 0.2$
$= 0.08$
KF made of two ions K^+ & F^-
$\therefore n(ions) = 2 \times 0.08 = 0.16$]

Question 2

Which of the following is the conjugate acid of HCO_3^- ?

A. H_2CO_4

B. H_2CO_3

C. CO_3^{2-}

D. HCO^{2-}

Question 3

[handwritten: $6+$ $14-$ $Cr^{6+}_{+3e^-} \rightarrow Cr^{3+}$]

During a redox reaction the dichromate ion, $Cr_2O_7^{2-}$ changes to the chromium ion, Cr^{3+}. For this reaction which statement is true?

A.   · chromium atoms have gained electrons and reached a lower oxidation state

B.   chromium atoms have gained electrons and reached a higher oxidation state

C.   chromium atoms have lost electrons and reached a high oxidation state

D.   chromium atoms have lost electrons and reached a high oxidation state

Question 4

Even though rainwater in Melbourne is unpolluted it is still slightly acidic. This is primarily due to the partial dissolution of which atmospheric gas?

A.   nitrogen dioxide

B.   sulphur dioxide

C.   carbon dioxide

D.   oxygen

Question 5

Consider the following chemical equation: $A + 2B \rightarrow 3C$

1 mol   2 mol

What is the amount, in mol, of C that would be produced if 6.0 mol of A reacted with 4.0 mol of B?

n(C)   What is limiting? A or (B)

A.   2.0

B.   3.0

C.   4.0

(D)   6.0

Question 6

Which of the following solutions contains the smallest amount of H_3O^+ ions?

A.   10 mL of 0.20 M sulphuric acid $> 2 \times 10^{-3}$

B.   10 mL of 0.20 M nitric acid 2×10^{-3}

(C.)   20 mL of 0.40 M ethanoic acid

D.   20 mL of 0.40 M hydrochloric acid 8×10^{-3}

Question 7

A household cleaning product was found to have a pH of 10.0. The H_3O^+ concentration is most likely to be

(A.) $10^{-10.0}$ M $pH = -\log(H_3O^+)$. $10^{-10.0}$

B. $10^{-4.0}$ M

C. $10^{10.0}$ M

D. $10^{4.0}$ M

Question 8

Which one of the following species is the most abundant in an aqueous solution of the weak acid, CH_3COOH?

(A.) CH_3COOH

B. CH_3COO-

C. OH^-

D. H_3O^+

Question 9

Which of the following best explains why pure water is a very poor conductor of electricity?

A.   The intermolecular hydrogen bonding requires a large amount of energy to disrupt it.

(B.)   Water molecules undergo self-ionisation to a very small extent only

C.   The latent heat of vaporisation of water is very high compared to many other liquids

D.   Only very few electrons can escape the covalent bonds in water molecules and become delocalised

Question 10 ~~ERROR~~ — take question [out] $S \rightleftharpoons S^{2+} + 2\bar{e}$ / $T^{2+} + 2e \rightleftharpoons T$.

When a piece of metal S is placed into a green coloured solution of TCl_2, the metal develops a coating and the solution colour lightens. A valid conclusion could be that

A.   chloride ions, Cl^-, are generally inert during chemical reactions

B.   the S^{2+} ions are more easily ~~oxidised~~ *reduced* than T^{2+} ions

C.   metal S is more easily reduced than metal T   *S > oxidant than T×*

D. ✗ metal T is more reactive than S   *i.e. T > reductant than S. ✗*

reductant
S > T
oxidant
T > S.

S + 2ē

Question 11

If 30 L of sulphur dioxide was completely reacted with excess oxygen according to the following equation

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$
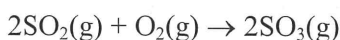
what volume of sulphur trioxide would form at SLC?

A.   0 L

B.   24.5 L

C.   30 L

D.   60 L

Question 12

Which of the following lists contains only amphiprotic substances?

A. H_2O, HCO_3^-, HPO_4^{2-}, H_2SO_4 ✗

B. $H_2PO_4^-$, HCl, SO_4^{2-}, CH_3COO^- ✗

C. NH_4^+, H_3O^+, PO_4^{3-}, OH^- ✗

D. HSO_4^-, $H_2PO_4^-$, HCO_3^-, H_2O

Question 13

When oxygen atoms become oxide ions, $O \xrightarrow{+2\bar{e}} O^{2-}$

A.   each oxygen atom accepts one electron. ✗

B.   oxidation has occurred.   ✗

C.   protons are transferred from the oxygen atoms. ✗

D.   the oxygen atom acts as an oxidant.

Question 14

Identical masses of the gases NH_3 and PH_3 were placed into separate containers, A and B, respectively. Both containers had the same volume and were at the same temperature.

Which one of the following statements concerning the two gases is correct?

A. The average kinetic energy of the particles in both containers is the same

B. The pressure in container B is higher than the pressure in container A

C. The average speed of the molecules in both containers is the same

D. The number of gas molecules in container A is less than the number in container B

Question 15

The solubility curves for two compounds are shown in the graph below
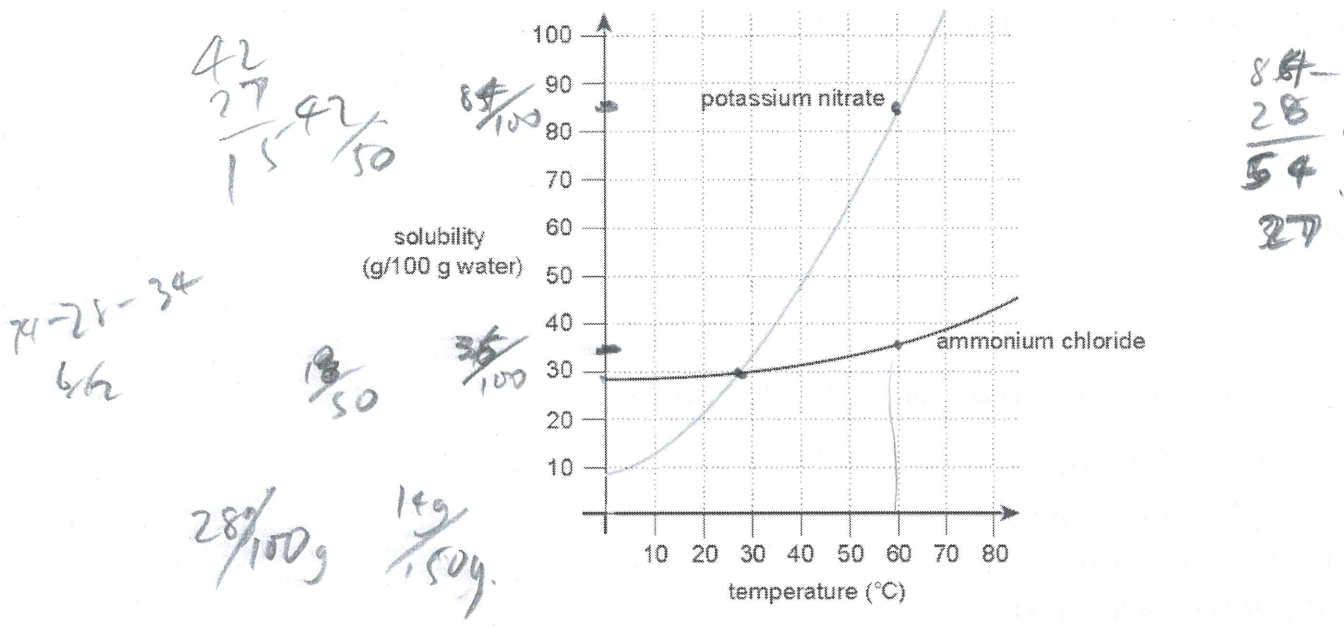
Saturated solutions of each solute were made, each using 50 grams of water, at the temperature where their solubilities are equivalent. Both solutions were then heated to 60 °C.

What mass of each solute must be added to the 60 °C solutions to achieve saturation of each solution?

	ammonium chloride	potassium nitrate
A.	6	54
B.	3	27
C.	36	84
D.	18	42

Question 16

Which of the following is not a redox reaction?

A. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

B. $Pb(s) + 2H^+(aq) \rightarrow Pb^{2+}(aq) + H_2(g)$

C. $O_3(g) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + H_2O(l) + O_2(g)$

D. $O_3(g) + 2I^-(aq) + H_2O(l) \rightarrow I_2(aq) + 3OH^-(aq)$

Question 17

Deionised water is rarely found in the natural environment because

A. water is immiscible with non-polar liquids

B. rain is deionised as it flows over rocks

C. water is purified by evaporation to form clouds

D. water is an excellent solvent

Question 18

When in an aqueous solution, which of the following species is least likely to form a chemical bond to a metal ion?

positively charged.

A. NH_4^+

B. NH_3

C. H_2O

D. F^-

Question 19

oxidation

Which of the following metals could not be used as the anode in the sacrificial electrochemical protection of a tin cathode?

What is less reactive than tin?

A. magnesium

B. zinc

C. lead

D. iron

Question 20

An unknown substance has a relatively high melting point and conducts electricity both as a solid and a liquid. The bonding holding this substance together is most likely to be

A. ionic

B. covalent

C. metallic

D. dipole-dipole

Question 21

The equation for aluminium metal production is: $2Al_2O_3(s) + 3C(s) \rightarrow 4Al(l) + 3CO_2(g)$

The percentage atom economy of this process is closest to

$3 \times 12 \quad 4 \times 27$

A.   32 %
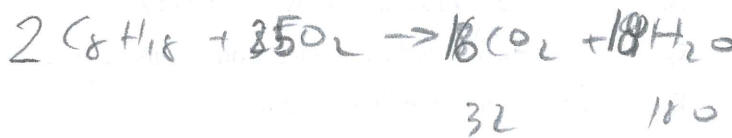
B.   45 %

C.   53 %

D.   78 %

$$\frac{(4 \times 27)}{2(2 \times 27 + 3 \times 16) + (3 \times 12)}$$

$$= \frac{108}{240} = 45\%$$

Question 22

Which of the following equations best represents the complete combustion of octane, C_8H_{18}, in excess oxygen?

A. $C_8H_{18(l)} + 8O_{2(g)} \rightarrow 8CO_{(g)} + 9H_{2(g)}$

B. $C_8H_{18(l)} + 4O_{2(g)} \rightarrow 8CO_{(g)} + 9H_{2(g)}$

C. $2C_8H_{18(l)} + 25O_{2(g)} \rightarrow 16CO_{2(g)} + 18H_2O_{(g)}$

D. $2C_8H_{18(l)} + 17O_{2(g)} \rightarrow 16CO_{(g)} + 18H_2O_{(g)}$

$2 C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

$32 \qquad 180$

Question 23

A standard solution is usually prepared in a

A.   volumetric flask

B.   conical flask

C.   beaker

D.   measuring cylinder

Question 24

Which list correctly orders the strength of bonding interactions?

A.   dispersion forces > dipole-dipole forces > hydrogen bonding > ionic bonding

B.   ionic bonding > dipole-dipole forces > hydrogen bonding > dispersion forces

C.   ionic bonding > hydrogen bonding > dipole-dipole forces > dispersion forces

D.   hydrogen bonding > dispersion forces > ionic bonding > dipole-dipole forces

Question 25

Which one of the following salts is insoluble in water?

A.   lead chloride

B.   ammonium chloride   ✗

C.   potassium chloride   ✗

D.   magnesium chloride

Question 26

Which one of the following covalent molecules would have a triangular pyramidal shape?

A. NH_3

B. CH_4

C. H_2O

D. HF

Question 27

Which electronic configuration is representative of the most reactive metal?

A. $1s^2 2s^2 2p^6 3s^1$ Na.

B. $1s^2 2s^2 2p^6 3s^2$ Mg

C. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ K

D. $1s^2 2s^2 2p^6 3s^1 3p^6 4s^2$ Ca

Question 28

Which of the following atmospheric gases has the least impact on the enhanced greenhouse effect?

A. CH_4

B. CO_2

C. N_2O

D. N_2

Question 29

Which of the following liquids is least likely to conduct electricity?

A. molten potassium bromide

B. hexane

C. mercury

D. an aqueous solution of sodium sulphate

Question 30

The relative atomic mass of magnesium is 24.31. The most important reason why it is not a whole number is that

A. magnesium atoms lose electrons when they react ✗

B. the relative atomic mass given is only an approximation ✗

C. not all atoms of magnesium have the same number of neutrons

D. the mass of the magnesium atom is compared to the mass of the ^{12}C isotope

This section contains 9 short-answer questions. Answer all questions in the spaces provided.
To obtain full marks for your responses you should:
- give simplified answers with an appropriate number of significant figures to all numerical questions;
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- include appropriate units for all quantities
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example $H_2(g)$; $NaCl(s)$.

Question 1

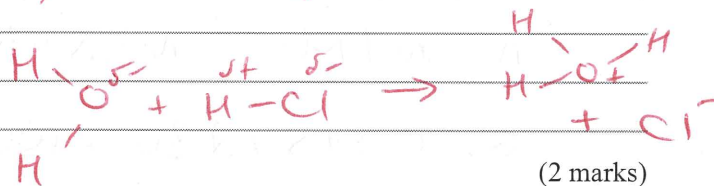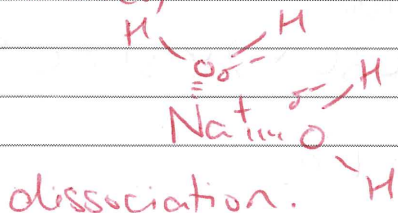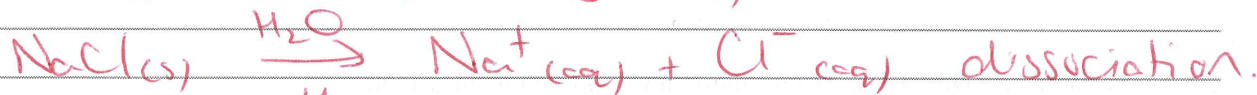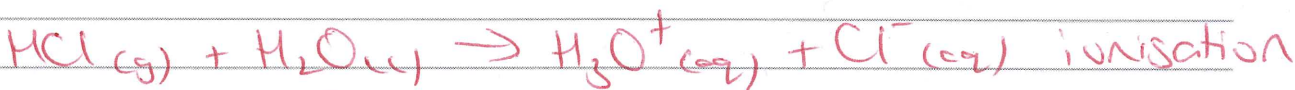Hydrogen chloride and sodium chloride are both soluble in water.

a. Name and briefly describe the type of bonding present in these two compounds.

HCl – covalent bonding (shared e^-)

NaCl – ionic bonding (donating/accepting e^- – electrostatic attraction $(+)(-)$)

(2 marks)

b. Briefly explain the differences in the mechanism of how these compounds dissolve in water. Using equations and a diagram may assist you.

$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$ ionisation

$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$ dissociation.

dissociation.

(2 marks)

c. Explain, using a diagram, why liquid water has a slightly greater density than ice.

density = mass/volume   ice has a > volume
∴ density is lower

also due to molecular arrangement
ice has a lattice structure
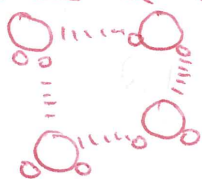
(2 marks)

Total 6 marks

Question 2

When 2.30 g of a magnesium alloy was treated with 1.20 M hydrochloric acid solution, 60.0 mL of the acid was required to react with all the magnesium.

a. The products of this reaction are magnesium chloride and hydrogen gas. Write the overall, balanced equation for the reaction of magnesium with the acid (include state symbols).

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

(2 marks)

b. What test could be used to identify the gas produced in the above reaction?

insert a lighted splint - if H_2 squeaky 'pop'

(1 mark)

c. Calculate the amount, in mole, of acid used in the reaction.

$n = c \times v$
$= 1.20 \times \left(\frac{60}{1000}\right) = 0.072$ mol

(1 mark)

d. Determine the amount, in mole, of magnesium in the 2.30 g of alloy

$n(Mg) = \frac{1}{2} \times 0.072 = 0.036$ mol

(1 mark)

e. What percentage, by mass, of magnesium was present in the sample?

$n = m/M$ ∴ $m = n \times M = 0.036 \times 24.31 = 0.875g$ Mg

So $0.875/2.30 \times 100 = 38.1\%$

(2 marks)

f. What volume, in litres, of hydrogen gas at 20.0 °C and 1.06×10^5 Pa would be produced in the reaction?

$PV = nRT$ ∴ $V = nRT/P$
$n(H_2) = 0.036$ mol ∴ $V = \dfrac{0.036 \times 8.31 \times (273+20)}{(1.06 \times 10^5)/1000}$
(1:1 ratio)
$= 0.827 L$

(3 marks)

g. What species is the reductant in this reaction?

$Mg_{(s)}$ goes from $0 \rightarrow +2$.

(1 mark)

Total 11 marks

Question 3

a. A sample of ammonia gas is taken from STP to SLC and ends up having a volume of 150 mL. What was the volume, in litres, of gas at STP?

$T_1 = 273 K$

$T_2 = 298 K$

$V_1 = ?$

$V_2 = 150 mL$

$\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$ ∴ $V_1 = \dfrac{V_2 T_1}{T_2}$

$= \dfrac{150 \times 273}{298}$

$= 137 mL$

(2 marks)

b. A sample of sulphur dioxide gas is held under the same conditions and has the same volume as ammonia gas.

   i. What conclusion can be reached from this information?

   Same # mol of gas occupies same volume at certain conditions.

(1 mark)

   ii. How would the average kinetic energy of the molecules in each sample of gas compare?

   average KE of gases is related to the average speed of movement and mass of particles by equation $KE = \dfrac{1}{2} \times m \times v^2$

(1 mark)

   iii. In which gas is the average speed of molecules greater? Explain your response.

   In NH_3 because mass of each molecule is lighter than SO_2 so overall speed will be greater.

(2 marks)

Total 6 marks

Question 4

The results obtained from a series of experiments using 0.5 M solutions of acid A and acid B are shown below.

Test	Acid A	Acid B
1. Electrical conductivity (in amperes) of each solution	0.45 A	0.023 A
2. Time taken for 20 mL of acid to react completely with identical pieces of zinc	4 minutes	25 minutes
3. Volume of acid required to react completely with 20 mL of 0.5 M NaOH(aq)	10 mL	20 mL

a. Explain why the acids gave different results in **both** tests 1 and 2.

Test 1 - one acid has more ions in solution (A) meaning it must ionise more
Test 2 - acid A must be stronger + produce more H^+ ions to react with Zn faster.

(2 marks)

b. Name the type of reaction which occurred in test 3.

neutralisation.

(1 mark)

c. What conclusion can be drawn about acid A from the results of test 3?

It is stronger and produces more H^+ ions per molecule of acid (it ionises fully)

(1 mark)

d. Calculate the pH of the 0.5 M NaOH solution at 25 °C

NaOH is strong so $[OH^-] = [NaOH]$
$= 0.5M$
$[H^+] \times [OH^-] = 10^{-14}$
$\therefore [H^+] = \dfrac{10^{-14}}{0.5} = 2 \times 10^{-14}$
$pH = -\log_{10}(2 \times 10^{-14}) = 13.7$
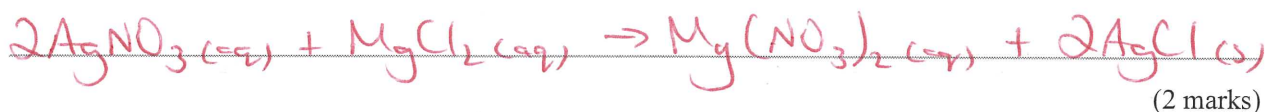
(3 marks)

Total 7 marks

Question 5

Two aqueous solutions were prepared: a 0.90 M silver nitrate solution and a 0.20 M magnesium chloride solution.

a. What mass of magnesium chloride would be needed to make a 0.20 M solution in a 250 mL volumetric flask?

$$n = c \times v \qquad n = 0.2 \times \left(\frac{250}{1000}\right) = 0.05 \text{ mol } MgCl_2$$

$$n = m/M \qquad \therefore m = n \times M = 0.05 \times (24.31 + (2 \times 35.5))$$

$$= 4.77g$$

$$\approx 4.8g$$

(2 marks)

b. Write a balanced equation, showing state symbols, for the reaction between the two solutions.

$$2AgNO_{3(aq)} + MgCl_{2(aq)} \rightarrow Mg(NO_3)_{2(aq)} + 2AgCl_{(s)}$$

(2 marks)

c. If 35 mL of 0.90 M silver nitrate solution is mixed with 75 mL of 0.20 M magnesium chloride solution, what reactant will be in excess, and by how many moles?

$$n = c \times v, \quad n(AgNO_3) = 0.90 \times \left(\frac{35}{1000}\right) = 0.0315 \text{ mol}$$

$$n(MgCl_2) = 0.20 \times \left(\frac{75}{1000}\right) = 0.015 \text{ mol}$$

$$2:1 \text{ ratio } AgNO_3 : MgCl_2 \text{ so } 0.03 \text{ mol } AgNO_3 \text{ needed}$$

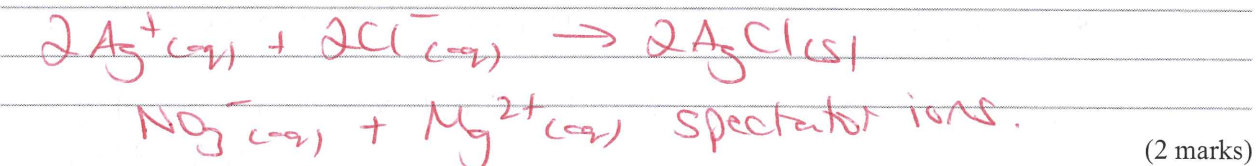$$AgNO_3 \text{ in XS by } (0.0315 - 0.03) = 0.0015 \text{ mol}.$$

(3 marks)

d. What is the name of the precipitate formed, and how many grams of it will be obtained?

$$n(AgCl) = \frac{2}{1} \times n(MgCl_2) = 2 \times 0.015 = 0.03 \text{ mol}$$

$$m = n \times M = 0.03 \times (107.9 + 35.5) = 4.3g$$

(3 marks)

e. Write the ionic equation for the reaction and give the formula of the spectator ions.

$$2Ag^+_{(aq)} + 2Cl^-_{(aq)} \rightarrow 2AgCl_{(s)}$$

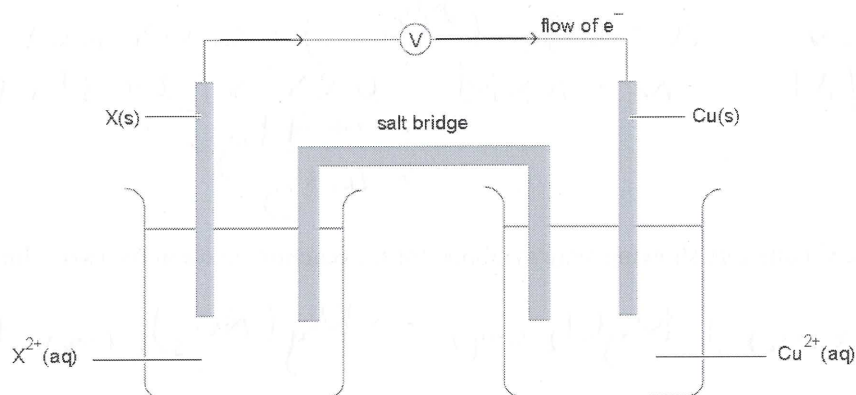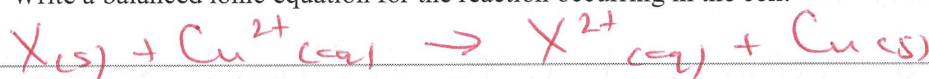$$NO_3^-{}_{(aq)} + Mg^{2+}_{(aq)} \text{ spectator ions}.$$

(2 marks)

Total 12 marks

Question 6

A galvanic cell is formed by the combination of two half-cells: $X^{2+}_{(aq)}/X_{(s)}$ and $Cu^{2+}_{(aq)}/Cu_{(s)}$. When the cell is operating, the electron flow is as shown.

a.   i.   Write a balanced ionic equation for the reaction occurring in the cell.

$X_{(s)} + Cu^{2+}_{(aq)} \rightarrow X^{2+}_{(aq)} + Cu_{(s)}$

   ii.   Which electrode (X or Cu) is the cathode?

Cu

   iii.   Which electrode (X or Cu) carries a negative charge?

X

   iv.   In which direction (towards X or towards Cu) do anions move through the salt bridge?

towards X

   v.   Give the symbol for a metal that would be suitable for use as metal X in this cell

Mg, Al, Fe, Zn, Pb, Sn, Co

(1 + 1 + 1 + 1 + 1 = 5 marks)

b.   In another galvanic cell the $Cu^{2+}_{(aq)}/Cu_{(s)}$ half-cell was connected to an Ag+(aq)/Ag(s) half-cell. After some time the silver electrode had changed in mass by 2.5 g. What is the expected change in mass of the copper electrode (remember to state whether it increases or decreases)?

$n(Ag) = 2.5/107.87 = 0.023 \, mol$

2:1 ratio Ag^+/Cu $n(Cu) = \frac{1}{2} \times 0.023 = 0.0116 \, mol$

$n \times M = M = 0.0116 \times 63.55 = 0.737g$ decrease
$\approx 0.74g$

$2Ag^+_{(aq)} + Cu_{(s)} \rightarrow 2Ag_{(s)} + Cu^{2+}_{(aq)}$

(4 marks)

Total 9 marks

Question 7

An organic compound has a percentage composition by mass of carbon 54.4 %, hydrogen 9.2 % and oxygen 36.4 %.

a. Calculate the empirical formula of the organic compound.

	C	H	O	
	54.4	9.2	36.4	
$\div A_r$	4.53	9.11	2.28	$EF = C_2H_4O$
$\div$ small	1.99	4.00	1	
$\approx$	2	4	1	

(3 marks)

b. A 1.32 g sample of the organic compound has a volume of 0.347 L at a temperature of 395 K and a pressure of 9.46×10^4 Pa.

i. Calculate the molar mass of the hydrocarbon

$$PV = nRT \quad \therefore \quad n = PV/RT = \frac{(9.46 \times 10^4)/1000 \times 0.347}{8.31 \times 395}$$

$$= 0.0100 \text{ mol}$$

$$n = m/M \quad \therefore \quad M = m/n \rightarrow 1.32/0.01 = 132 \text{ g mol}^{-1}$$

ii. Determine the molecular formula of the organic compound.
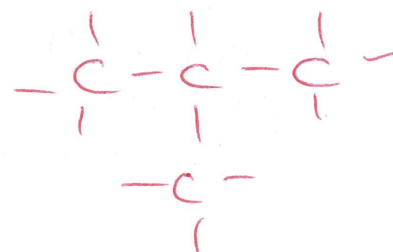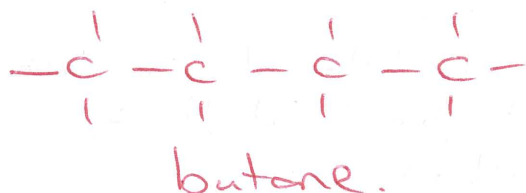
$$M(C_2H_4O) = (2 \times 12.01) + (4 \times 1.01) + 16.00 = 44.06 \text{ g mol}^{-1}$$
$$= 44.1 \text{ g mol}^{-1}$$

$$132/44.1 = 2.99 \approx 3 \quad MF = 3 \times EF = C_6H_{12}O_3$$

(3 + 2 = 5 marks)

c. Draw and name all the structural isomers having the molecular formula, C_4H_{10}


butane.

methylpropane.

(4 marks)

Total 12 marks

Question 8

A number of methods are in operation for the desalination of seawater, including distillation and reverse osmosis.

The Victorian desalination plant uses **reverse osmosis** to purify sea water, as shown in the simplified diagram below. The electricity needed to drive the process is obtained from a coal-fired power station.
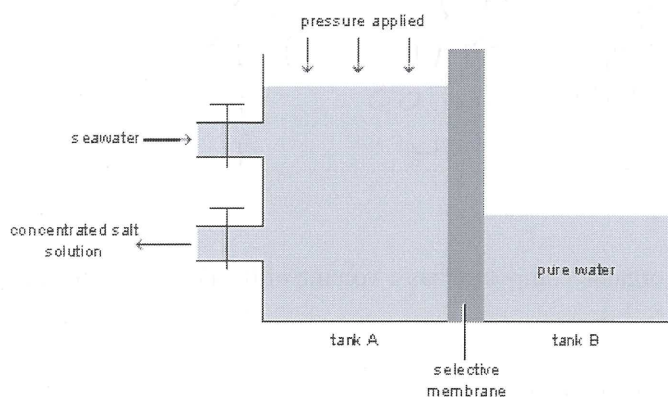
a.   The concentration of sodium chloride in a saltwater sample was 3.1 % w/v. Express this concentration of sodium chloride in mol L^{-1}

3.1% w/v means 3.1g NaCl per 100mL solution
$n(NaCl) = m/M = 3.1/(22.99+35.5) = 0.053$ mol

If 0.053 mol NaCl in 100mL
must be 0.053 × 10 mol in a L → 0.53 mol L^{-1}

(3 marks)

b.   Explain why the output from tank A has a higher concentration of ions than seawater.

Na^+ and Cl^- ions cannot pass through selective membrane. Water is removed but # ions stays same # water molecules ↓ so conc ↑

(1 mark)

c.   Give a specific example from the Victorian desalination plant using the reverse osmosis process which **does not** illustrate the '**prevent pollution**' principle of green chemistry.
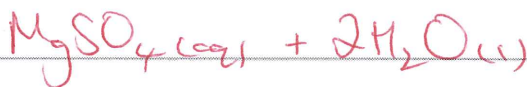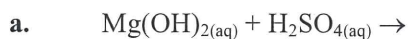
energy inefficient - uses lots of electricity generated from coal power stations ∴ creates pollution.
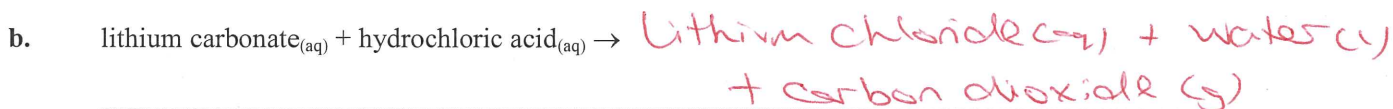
(1 mark)

Total = 5 marks

Question 9

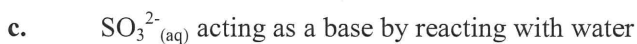Write complete and balanced equations for the following partial equations (including state symbols).
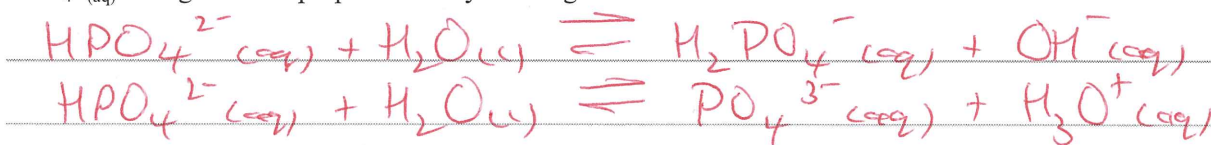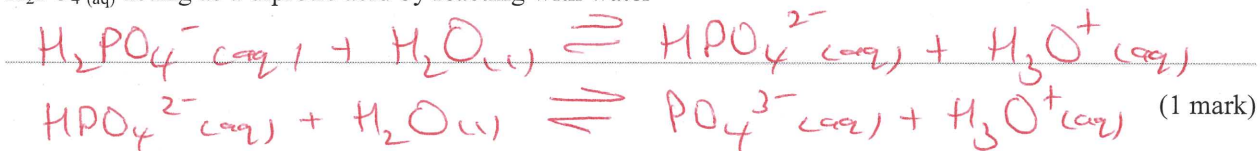
a. $Mg(OH)_{2(aq)} + H_2SO_{4(aq)} \rightarrow$

$MgSO_{4(aq)} + 2H_2O_{(l)}$

(1 mark)

b. lithium carbonate$_{(aq)}$ + hydrochloric acid$_{(aq)}$ → Lithium chloride$_{(aq)}$ + water$_{(l)}$ + carbon dioxide$_{(g)}$

(1 mark)

c. $SO_3^{2-}{}_{(aq)}$ acting as a base by reacting with water

$SO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons HSO_3^{-}{}_{(aq)} + OH^{-}{}_{(aq)}$

(1 mark)

d. $HPO_4^{2-}{}_{(aq)}$ acting as an amphiprotic ion by reacting with water

$HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_2PO_4^{-}{}_{(aq)} + OH^{-}{}_{(aq)}$
$HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons PO_4^{3-}{}_{(aq)} + H_3O^{+}{}_{(aq)}$

(1 mark)

e. $H_2PO_4^{-}{}_{(aq)}$ acting as a diprotic acid by reacting with water

$H_2PO_4^{-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons HPO_4^{2-}{}_{(aq)} + H_3O^{+}{}_{(aq)}$
$HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons PO_4^{3-}{}_{(aq)} + H_3O^{+}{}_{(aq)}$

(1 mark)

Total = 5 marks

END OF QUESTION AND ANSWER BOOKLET