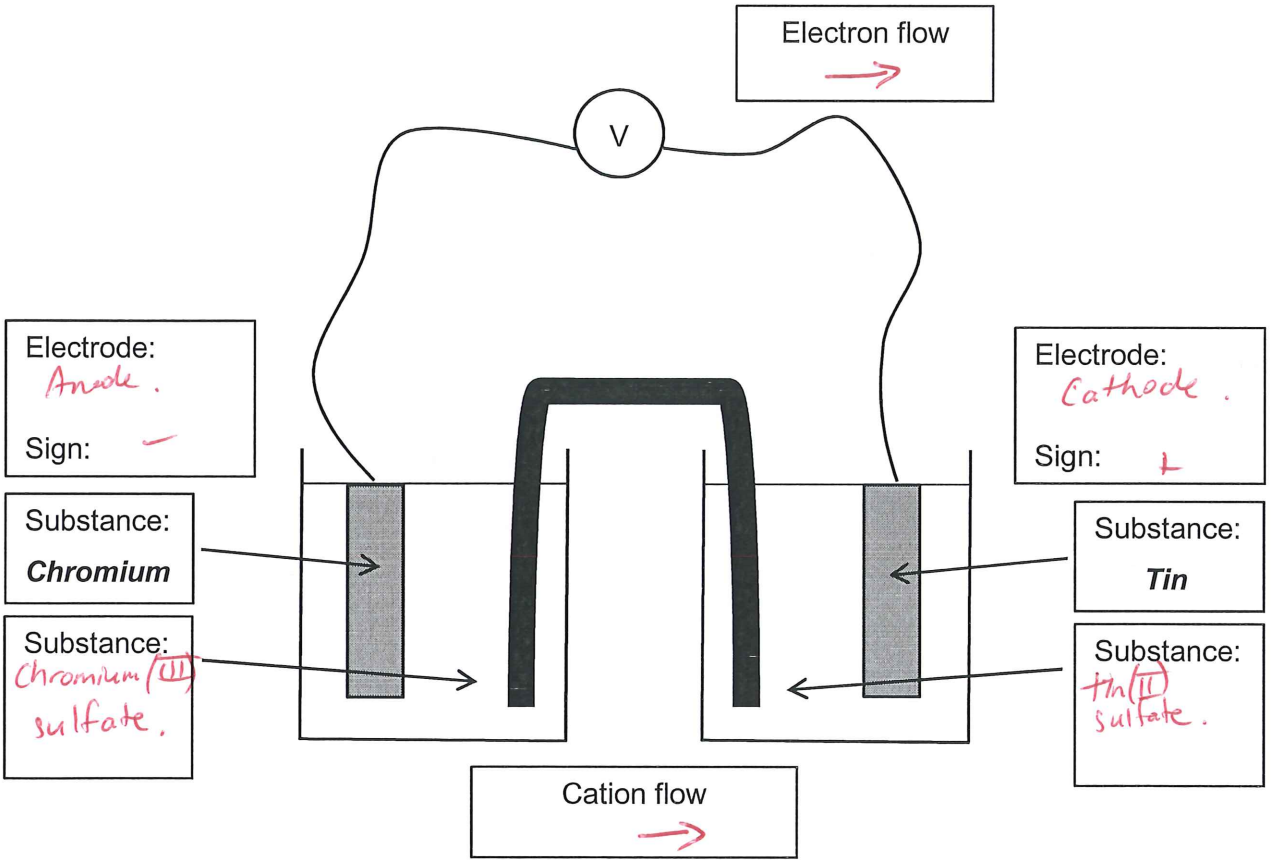
Task 9 (5%) Electrochemical Cells Extended Response **Name:** Solutions.

Question 1

The Daniell cell was invented in 1836 and was one of the earliest batteries to be designed. Essentially, the Daniell cell can be thought of as two half-cells consisting of a copper electrode submerged in copper(II) sulfate solution (Cu/Cu^{2+}) and a zinc electrode submerged in zinc sulfate solution (Zn/Zn^{2+}). In the original design, a porous clay pot was used to separate the half-cells and act as what we now call the salt bridge. The EMF produced by the Daniell cell is 1.1 V under standard conditions.

A chemistry class was studying the basic design of the Daniell cell and decided to investigate the effect of changing the metals used for each electrode/electrolyte. They decided to construct a cell using tin metal, chromium metal, tin(II) sulfate solution and chromium(III) sulfate solution. They set up their apparatus as shown in the diagram below.



(a) Label all remaining components of the cell in the diagram above, including: **(6 marks)**

(i) cathode and anode −1
(ii) sign of each electrode −1
(iii) substance used for each half-cell electrolyte −2
(iv) direction of electron and cation flow

(b) Note two observations that would be made as this electrochemical cell operates. **(2 marks)**

Chromium electrode reduces in size - deeper green electrolyte −(1)

Tin electrode gets larger −(1)

The overall equation for the operation of this electrochemical cell is;

$$3\ Sn^{2+}(aq) + 2\ Cr(s) \rightarrow 3\ Sn(s) + 2\ Cr^{3+}(aq)$$

Just like the Daniell cell, the cell designed by the students is a primary cell, which means it cannot be recharged. Therefore, over time the reactants will run out, as the chemicals stored within the electrochemical cell are used to produce electricity.

If the chromium electrode has a mass of 36.2 g and there was 475 mL of 2.10 mol L^{-1} tin(II) sulfate solution present;

(c) Determine the limiting reagent. **(5 marks)**

$n(Cr) = \frac{36.2}{52}$

$n(Cr) = 0.696$ moles. -(1)

$n(SnSO_4) = n(Sn^{2+}) = c \cdot v$

$n(Sn^{2+}) = 2.10 \times 0.475$

$n(Sn^{2+}) = 0.9975$ mole -(1)

ratio $3\ Sn^{2+} : 2\ Cr$ -(1)

data $0.9975 : 0.696$ -(1)

ideal 0.665

$\therefore$ LR = Sn^{2+} -(1)

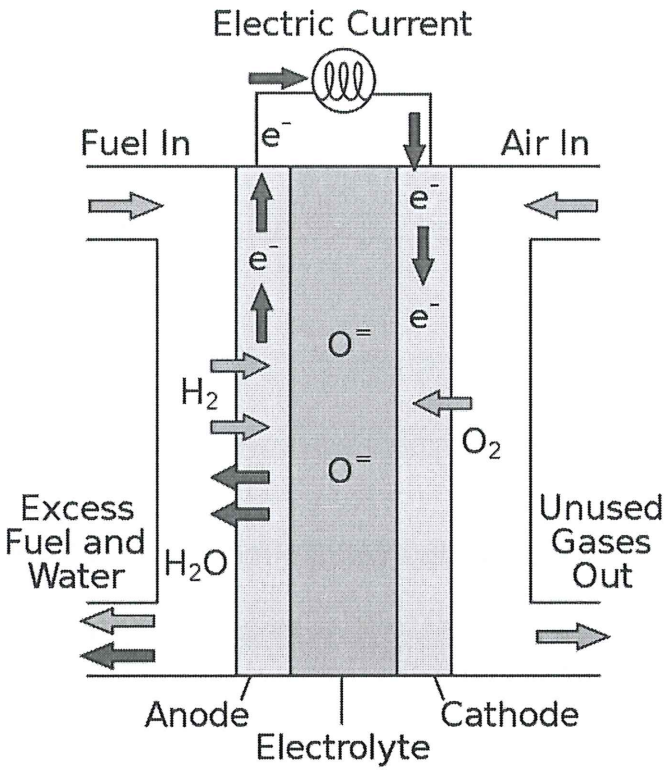
Question 2

Fuel cells are common amongst applications such as the aerospace and automotive industries.

Consider the following specific fuel cell.

a) Describe and explain the mechanisms that are taking place.

(5 marks)



As the fuel (H_2) enters at the anode, the atoms are ionised in to $H^+ + e^-$. (1)

The e^- travel through the external circuit as current. (1)

When O_2 enters the cathode, it captures the e^-'s then travels through the electolyte to the anode where it combines with the H^+. (1)

The oxygen and hydrogen form water (1).

b) Describe and explain 3 different limitations/disadvantages of the fuel cell.

(3 marks)

1) H_2 - explosive

2) O_2 - corrosive

3) Expensive components.

Any 3 different limitations.

Question 3

A group of students perform a series of experiment's where the voltage of various cells were measured.

Table 1: The recorded voltage for various electrochemical cells

Cell cations	Measured Voltage (volts)
$Ag//Ag^+$ $Cu//Cu^{2+}$	1.14 V
$Cu//Cu^{2+}$ $Sn//Sn^{2+}$	0.20 V
$Sn//Sn^{2+}$ $Ag//Ag^+$	0.94 V
$Ag//Ag^+$ $Mg//Mg^{2+}$	3.16 V
$Cu//Cu^{2+}$ $Mg//Mg^{2+}$	2.02 V

a) Graph the results. **(4 marks)**

b) Another group of students measured a sixth cell and measured the voltage. The cell involved $Mg//^{Mg2+}$ and an unknown metal. The voltage measured was +3.81V.

What is the unknown metal and account for the voltage? **(3 marks)**

(1)

Gold (Au). $Au^{3+} + 3e^- \rightarrow Au$ +1.50

$Mg \rightarrow Mg^{2+} + 2e$ +2.36 (1)

3.86 V

Difference - resistance in the wire. (1)

c) Another group planned to do another series of electrochemical cells. The following is the list of their equipment.

List 1: Electrochemical Cells Equipment

Metal strips - nickel, cobalt, iron, chromium, silver and aluminium
Metal solutions 0.001 M - nickel sulfate
- cobalt chloride
- chromium iodide
- silver hydroxide
- aluminium nitrate

Filter paper
Salt bridge solution – 0.1 M sodium chloride
100 mL beakers

Any (3) 1 each.

1) Critique the list. **(3 marks)**

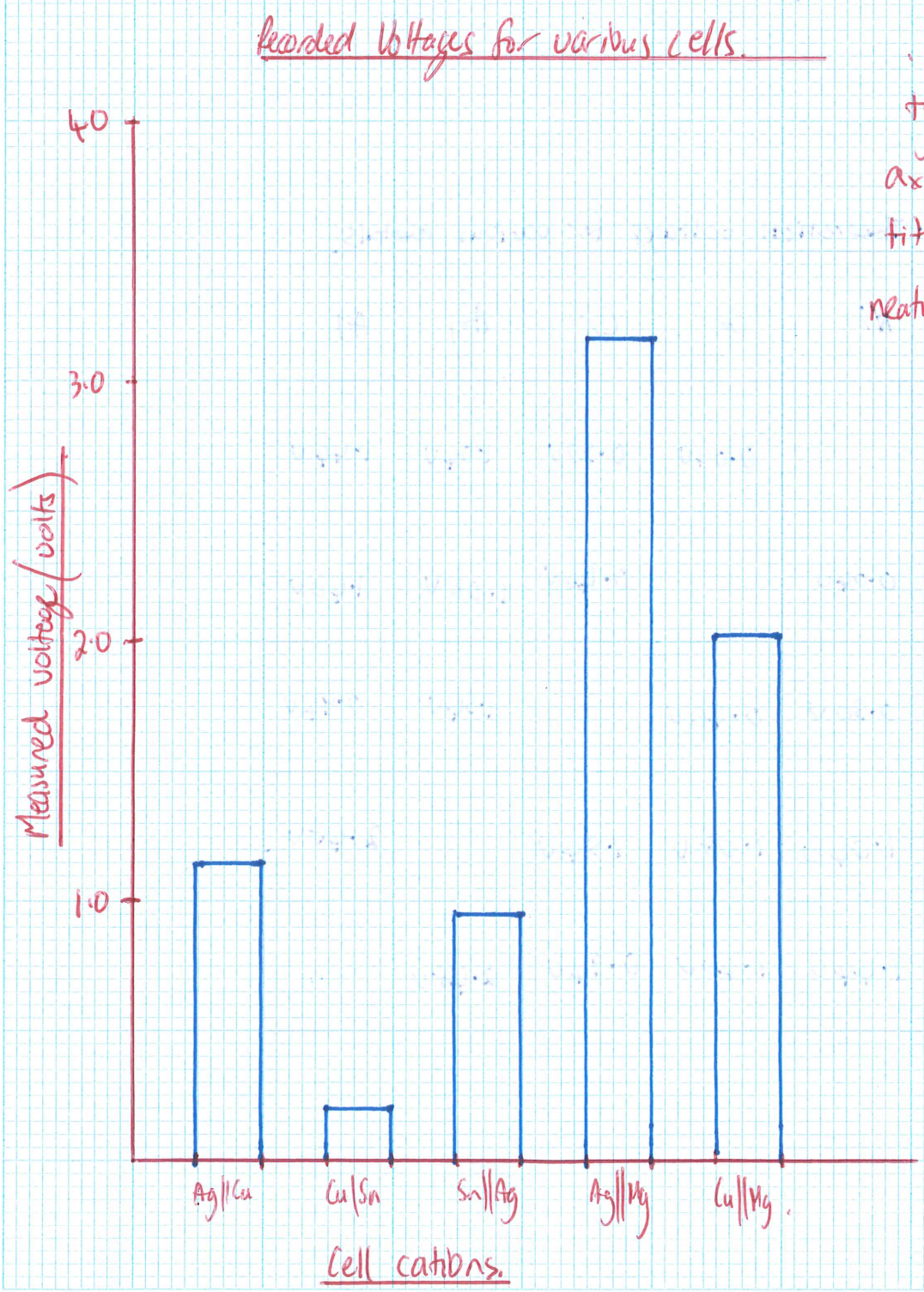
- lack of iron solution
- no multimeter and wires.
- salt bridge solution - will precipitate with → ($Ag^+ + Cl^- \rightarrow AgCl_{(s)}$)
- concentration too low. Unsaturated solution
- silver hydroxide slightly solution.

2) Create a table and enter the theoretical data. **(3 marks)**

→ Table structure (ie ruled) + title. – (1).
→ Combination number – (1)
→ Data – (1).

End of Task 9 **Marks: _____/34 Marks**

Question 3 a).



type - (1)
axis - (1)
title - (1)
neatness - (1)

(4) total.

Question 3 a).

Title: Theoretical voltages for various metals

	Ni	Co	Cr	Ag	Al
Ni		0.04V	0.50V	1.04V	1.44V
Co	0.04V		0.46V	1.08V	1.40V
Cr	0.50V	0.46V		1.54V	0.94V
Ag	1.04V	1.08V	1.54V		2.48V
Al	1.44V	1.40V	0.94V	2.48V	