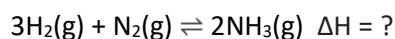Revision Unit 3-4 – worksheet- equilibrium, organic, experimental technique and galvanic ells

1. The balanced chemical equation for the formation of ammonia is given below.
$$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = ?$$

   a. Write the expression for the reaction quotient and give the units that this quotient is expressed.

$$\frac{[NH_3]^2}{[H_2]^3[N_2]} = Q$$

   b. Give the balanced thermochemical equation for the formation of ammonia given that the formation of 0.170 grams of ammonia released 960 J of energy

   Step 1 Find the mol of ammonia
   => 0.170 / 17.0 = 0.0100 mol
   Step 2 Find the energy released per mol of ammonia
   => 0.960 / 0.0100 = 96 kJ mol$^-$

   c. A student performed two experiments whereby a known amount of ammonia was injected into a 10 litre sealed vessel at 30°C and allowed to reach equilibrium. At which point the concentrations of NH_3, N_2 and H_2 were measured.
   Experiment 1 – 17.0 grams of ammonia injected into the vessel
   Experiment 2 – 1.70 grams of ammonia injected into the vessel

   i. Give the reaction quotient for the reaction taking place in the sealed container.

   Since the reaction taking place is

   $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$

$$\frac{[H_2]^3[N_2]}{[NH_3]^2} = Q$$

   ii. In experiment one when equilibrium was reached the following relationship was observed. $[N_2] = [NH_3]$. Select from the three alternatives below how this relationship changes in experiment 2 and provide an explanation to justify your selection.

   $[N_2] < [NH_3]$, $[N_2] = [NH_3]$, $\boxed{[N_2] > [NH_3]}$

   Since only 1.7 g of NH_3 is placed in the sealed vessel in experiment 2 less H_2 is formed. It is like removing NH_3 from the system and allowing the system to adjust to the change by moving to the right to partially undo the removal of NH_3.

$$\frac{[H_2]^3[N_2]}{[NH_3]^2} = Q$$

   The value of Q at equilibrium does not change unless temperature changes and we call this value the equilibrium constant. Since temperature remains constant, in order for Q to remain the same the value of the expression $[N_2]/[NH_3]^2$ must increase as $[H_2]$ has decreased. Therefore $[N_2] > [NH_3]$.

d. Select from the three alternatives below in describing the **rate** of reaction in experiment 1 (E1) compared to experiment 2 (E2). Provide an explanation to justify your selection.

E1 > E2,   E1 < E2,   E1 = E2

Greater concentration of reactants increases the frequency of collisions. This will also increase the frequency of collisions amongst particles that have the right amount of energy, activation energy, to undergo fruitful collisions.

e. Under what condition/s will the value of the reaction quotient change.

Temperature change

f. In another experiment, at a different temperature, 34.0 grams of ammonia was injected into a 10 L, sealed vessel and allowed to reach equilibrium. Once equilibrium was reached the gas mixture was analysed and found to contain 17.00 grams of ammonia. Calculate the value of equilibrium constant at this temperature with the appropriate units. Give the answer to the right number of significant figures.

	$[NH_3]$	$[N_2]$	$[H_2]$
Before reaction	0.20 M	0	0
After reaction	0.10 M	0.050 M	0.15 M

$$\frac{[0.15]^3[0.050]}{[0.10]^2} = Q = 0.017 \ M^2$$

2. Two galvanic cells are shown below wired together.
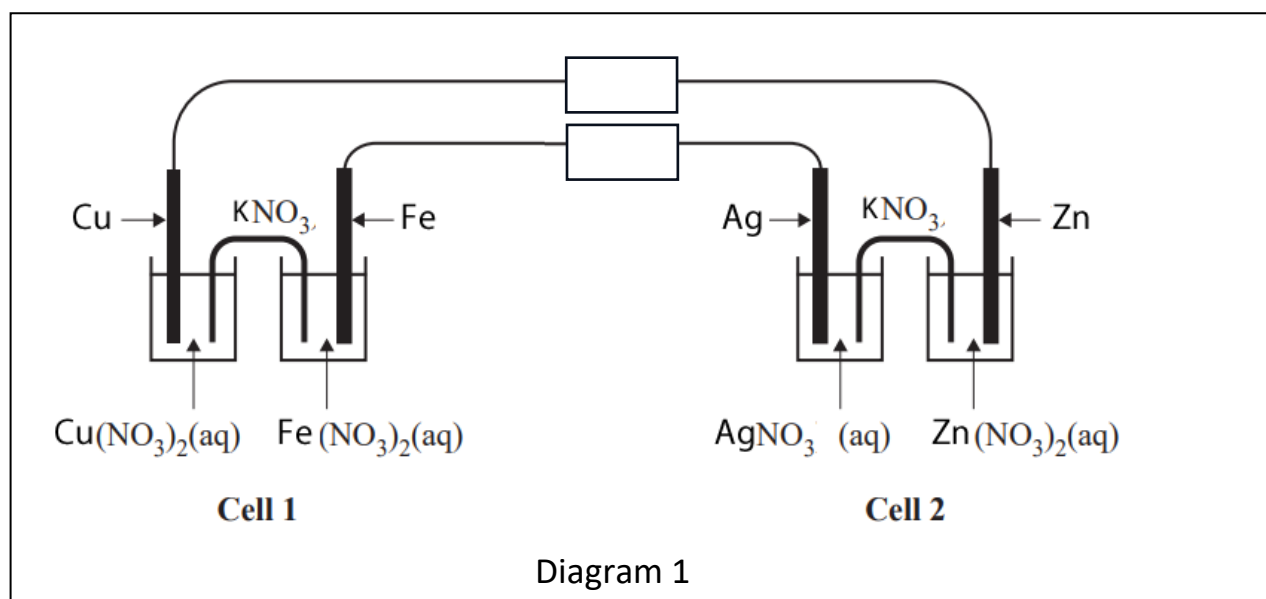
Diagram 1

a. Using the information given in diagram 1 answer the following true/false questions.

i. When the circuit is complete, a spontaneous reaction takes place in cell 1.
True / ⟨False⟩
Justify your answer.

⊖ *According to ⊕ E^o table found in the data-boo⊕ cell 1, on its own ⊖ should produce a cell voltage of $(E^o (Cu^{2+}/Cu - Fe^{2+}/Fe) = +0.34V - -0.44V) = 0.78V$ However it si hooked up to Cell 2 that produces a cell voltage of 1.56 V.*
$(E^o (Ag^+/Ag - Zn^{2+}/Zn) = +0.80V - -0.76V) = 1.56V$
Clearly cell 2 drives the non-spontaneous reactions in cell 1 and forces cell 1 to act as an electrolytic cell converting electrical energy into chemical energy.
The overall reaction taking place in Cell:
$1 - Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$
$2 - Zn(s) + 2Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$
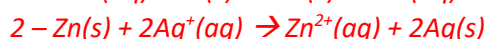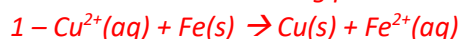
ii. Chemical energy is converted into electrical energy in cell 2. ⟨True⟩ / False
Justify your answer.

See answer to i. above

iii. Cell 1 acts as an electrolytic cell as it is being charged. ⟨True⟩ / False
Justify your answer.

See answer to i. above

iv. Cell 2 is not able to charge cell 1. True / ⟨False⟩
Justify your answer.

Cell 2 to produces a voltage that is greater that the voltage produced be cell 1 hence it is capable of recharging Cell 1 as long as the cells are connected properly. In this case the positive electrode from cell 1 is connected to the positive electrode of cell 2 and similar with the negative electrodes. Which is the right away of connecting a cell to a power source(cell 2) for recharging.

b. Draw the direction of electron flow by placing an arrow in the box provided in diagram 1.

c. Give the polarity of each electrode in the red circles provided in diagram 1.

d. Towards which electrode do the cations in the salt bridge move to in:

Cell 1 _____*K^+ ions travel to the Cu half cell*

Cell 2 _____ *K^+ ions travel to the Ag half cell*

e. Give the half equations occurring in each cell.
Cell 1 anode _*$Cu(s) \rightarrow Cu^{2+} (aq) + 2e$*_____ Cathode ___ *$Fe^{2+} (aq) + 2e \rightarrow Fe(s)$*

Cell 2 anode ___ *$Zn(s) \rightarrow Zn^{2+} (aq) + 2e$* ___ Cathode _____ *$Ag^+(aq) + e \rightarrow Ag (s)$*

f. This particular setup is allowed to run for 10.00 minutes producing a current of 1.45 A. After which the mass of each electrode was measured.

    i.   Which electrode gained the most mass? ____*Silver*__

    ii.   Calculate the mass, in grams, gained by this electrode.

Step 1 – find the charge produced

=> Q ($_{charge\ (C)}$)= It

=> Q = 1.45 X 10.00 X 60 = 870 C

Step 2 Find the mol of electrons

=> 870 / 96500 = 9.02 X 10^{-3} mol

Step 3 find the mol of silver (Ag^{+}+ e → Ag(s))

=> 9.02 X 10^{-3}

Step 4 find the mass of silver

=> 9.02 X 10^{-3} X 108 = 0.974 grams

    iii.   Describe how the colour in the half cell containing the copper electrode in cell 1 changes as the setup is allowed to operate over the 10 minute period. Give a detailed explanation using appropriate chemical equations.

It will turn a deeper blue as the following reaction is forced to proceed with the input of electrical energy.

Cu(s) → Cu^{2+} (aq) + 2e
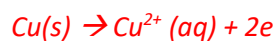
3. Consider the organic pathway and the spectra of compounds A and B shown below.

Compound A

Compound B

$$X \xrightarrow[\substack{H_2O \\ 300\ ^\circ C}]{H_3PO_4(s)} \begin{array}{c} Y \xrightarrow{T} B \\ Z \longrightarrow A \xrightarrow[H^+(aq)]{Cr_2O_7^{2-}(aq)} W \end{array}$$

a. A pure, 0.880 gram sample of the straight chain organic compound W was dissolved in 20.0 mL of water. This solution was then titrated against a standard 0.330 M NaOH using phenolphthalein as an indicator to obtain an average titre of 30.30 mL.

   i.   Calculate the mol of NaOH in the average titre.

   This is most likely an acid base neutrlisation reaction between NaOH and an organic acid.

   The mol of NaOH in an average titre = C X V = 0.330 X 0.03030 = 0.0100

   ii.   Calculate the molar mass of compound W

   Step 1 find the mol of acid that reacted with 0.0100 mol of NaOH. Since NaOH reacts in a 1:1 ratio with an organic acid the mol of the organic acid is also 0.0100.
   Step 2 find the molar mass of the acid
   => molar mass = mass/mol = 0.880 / 0.01 = 88.0 g/mol

   iii.   Identify compound W.
   A straight chain organic acid with molar mass 88.0 g/mol can only be butanoic acid.

b. Identify the following reactants/reagents
   X __*But-1-ene*_____

   Y ___ *Butan-2-ol* _____ *Addition reaction*

   Z ___ *Butan-1-ol* _____ *Addition reaction*

   T _____$Cr_2O_7^{2-} / H^+$ __ or __MnO_4^- / H^+_____

c. Draw the structural formulae of compounds A and B in the space below. Justify your answer with the use of the ^{1}HNMR spectra of A and B.

A *See structural formula above in ^{i}HNMR spectrum.*

Reference to the splitting patterns and ppm as per databooklet is necessary.

B *See structural formula above in ^{i}HNMR spectrum*

Reference to the splitting patterns and as ppm per databooklet is necessary.

d. Reversed-phase chromatography was used to separate a mixture of compounds A, X, Z and W. The chromatogram is shown below.
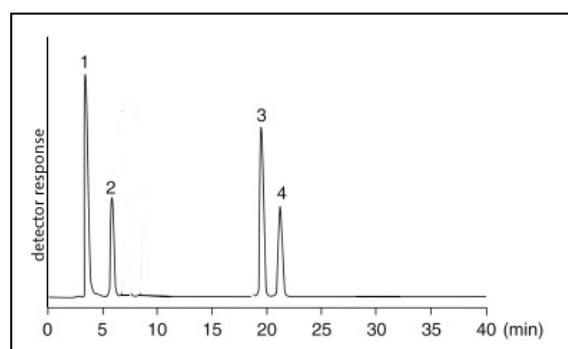

i. Give the appropriate peak number to each compound. Justify your choice.

The molecular structure of each molecule must be taken into account in order to see which is more polar. Reverse phase has a non-polar stationary phase and relatively polar mobile phase.
The more polar molecules will have a shorter retention time than non-polar molecules as they will interact more with eh mobile and be moved down the column quickly.
The most polar molecule is butanoic acid(W). This is number 1
The next most polar molecule is Butan-1-ol(Z). This is number 2
The next most polar molecule is Butan-2-ol(Y). This is number 3

The least polar and the one that will interact the most with the stationary phase will have the longest retention time and that is but-1-ene (X). This is number 4.

ii.   Another mixture was analysed under exactly the same conditions and using the same column as the mixture in i. above. The chromatogram shown below was achieved. Does this new mixture contain any of the four compounds A, X, Z or W.
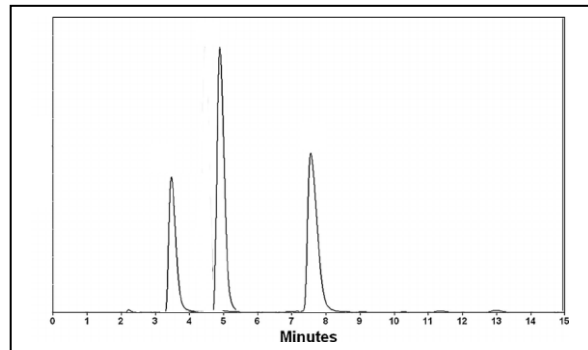
Retention time identifies the molecular compound. In this case both spectra have a compound at 3.5 which is butanoic acid. Hence butanoic acid is in both mixtures.

iii.   Outline a procedure by which the concentration of the molecule identified in ii. above can be accurately obtained.
Step 1 – prepare standard solutions of butanoic acid. These standards should cover the expected concentration range of the butanoic acid in the mixture.
Step 2 – measure the area under the peak produced by each solution.
Step 3 – draw a calibration curve of area vs concentration.
Step 4 – read the area under the curve at 3.5 minutes from the chromatogram of the mixture and using the calibration curve read the concentration of butanoic acid.
Step 5 – for greater accuracy the concentration of the butanoic acid in the mixture must fall within the concentrations measured to develop the calibration curve. In other words you can not extrapolate from the calibration curve to concentration.

4. A student was asked to devise an experimental procedure to calculate Faraday's constant from first principles. The experimental setup is shown on the right in diagram 2.

   The student decided to use a Hoffman voltameter to produce a measurable volume of hydrogen gas at SLC.

   Below is the step-by-step procedure as written by the student.

   Step 1 – Setup the Hoffman voltameter as shown in diagram 2 using a 3M H_2SO_4 solution. Local tap water was used to make the acid solution.
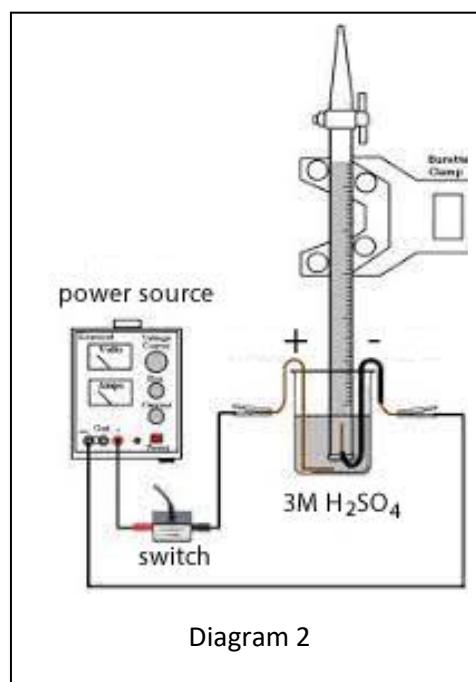
   Step 2 – Set the power source to produce a constant current of 1.322 A at 3.00 volts.

   Step 3 – Take a reading of the water level in the calibrated tube. Record the result

   Step 4 – Turn on the switch for 1.00 minute.

   Step 5 – Turn the switch off and record the final water level.

   Step 6 – Repeat steps 3 – 5, 4 more times.

power source

3M H_2SO_4

switch

Diagram 2

Results are shown below for two students, in two different cities in Australia, working with the same procedure.

Trial	Volume of H_2(mL)	Volume of H_2(mL)
	Student-1	Student-2
1	11.00	8.00
2	9.00	7.98
3	13.99	8.01
4	6.99	8.00
5	10.00	7.99

Below is the working out of student 1 attempt at using the data to solve for Faraday's constant.

a. *Student-1 averaged the results obtained from the 5 trials to calculate Faraday's constant.*

   i. *Using student-1's averaged results calculate Faraday's constant.*

   Step 1 mol of H_2 gas
   => 0.0102 /24.8 = 0.000411
   Step 2 mol of electrons (H^+(aq) + 2e → H_2(g))
   => 0.000411 X 2 = 0.000822
   Step 3 Charge delivered
   => Q = It = 1.322 X 60 = 79.32 C
   Step 4 Charge per mol of electrons
   => 79.32 / 0.000822 = 96496 C mol⁻

ii.   *Are the results from student-1's trials more accurate than student-2's results.*
        Justify your answer showing all your calculations in the space below.

Yes student-1's results, when averaged out, give a very accurate value for Faraday's
constant. Student-2's results however do not.
Step 1 mol of H_2 gas
=> 0.00800 /24.8 = 0.000322
Step 2 mol of electrons ($H^+(aq) + 2e \rightarrow H_2(g)$)
=> 0.000322 X 2 = 0.000644
Step 3 Charge delivered
=> Q = It = 1.322 X 60 = 79.32 C
Step 4 Charge per mol of electrons
=> 79.32 / 0.000644 = 123168 C mol^-

iii.   *What type of error leads to student-1's data? Justify your answer.*

Random error
Random errors lead to a lack of precision which is obvious in the data set of student-1.

iv.   *What type of error leads to student-2' s data? Justify your answer.*

Systematic error. Systematic errors have a consistent impact on the measurement, these
errors can produce precise results that lead to an inaccurate result..

_____

v.   *Compare each students results by placing a tick in the appropriate box in the*
        table below.

Student	More Accurate	More precise	Repeatable
1			
2			

vi.   *Are the results valid? Justify your answer.*

No . To be valid the procedure must have only one D.I.and one I.V.. The fact that students
are using local tap water to formulate the 3M H_2SO_4 solution causes an added variable
that is not controlled for.

vii.   *Offer one improvement to the procedure and suggest why your improvement will*
        lead to better outcomes.

Use distilled water. Having a 3M H_2SO_4 solution that is consistent, will contribute the
validity of the results. Water quality varies with unknown impurities present that may
influence the concentration of the acid solution.