



GOVERNMENT OF  
NEWFOUNDLAND AND LABRADOR

Department of Education

Evaluation, Testing, and Certification Division

## Chemistry 3202 Course Clarifications

This document contains detailed marking schemes for items that are typically asked by teachers or items that students often have difficulty with. Common student errors or misconceptions are highlighted and some teaching suggestions are provided. This document will be reviewed by teachers every year and any recommended additions or corrections will be made at that time. Please contact me with any comments regarding this document. ([ronsmith@gov.nl.ca](mailto:ronsmith@gov.nl.ca))

### Unit 1

**Concept 1.1:** Potential Energy Diagrams

**Issue:** Diagrams not fully labeled

**Item Example:**

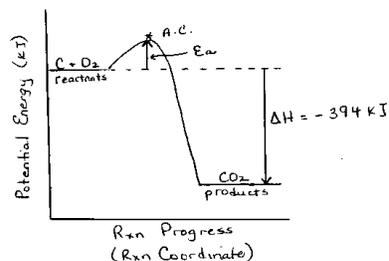
**3%** The activation energy for the reaction below is 100 kJ



- Clearly draw and label the potential energy diagram for this reaction.
- Determine the activation energy for the reverse reaction.

**Answer with Marking Scheme and Explanation:**

- A labeled diagram must include:
  - labeled axes (**0.5 mark**)
  - location of reactants and products (**0.5 mark**)
  - $E_a$  & activated complex site (**0.5 mark**)
  - $\Delta H$  (**0.5 mark**)
  - exothermic shape (**0.5 mark**)



- $E_a$  (reverse) = 394 kJ + 100 kJ = 494 kJ (**0.5 mark**)

**Common Errors and Misconceptions:**

- Students do not fully label all parts unless prompted by the question.
- Students confuse the shape for an endothermic and exothermic reaction.

**Notes:**

- 1) Teachers should emphasize that the height of the hump and height difference between energy of products and energy of reactants is not important; products must be lower in energy than reactants (exothermic; energy is a product)
- 2) Another type of question applied to potential energy diagrams could be:
  - a) show the effect of a catalyst.
  - b) draw a P.E. diagram for a given reaction mechanism, or given a P.E. diagram answer questions about a reaction mechanism (see p. 30 of curriculum guide)

**Concept 1.2:** Applying Collision Theory

**Issue:** This type of question is performed poorly; answers not given in terms of applying collision theory

**Item Example:**

- 2%** Using collision theory, explain the effect of the following factors on the rate at which calcium carbonate cubes react with hydrochloric acid.
- i) crushing the cubes into smaller pieces
  - ii) moving the reaction vessel from the lab bench to a freezer

**Answer with Marking Scheme and Explanation:**

- i) Crushing the cubes increases the surface area. More particles are available for collisions thus the number of collisions between reactant particles increase. As a result the number of successful collisions will increase, thus rate will increase.

**0.5 mark** for the effect on rate, **0.5 mark** for explanation of increase in number of successful collisions

- ii) moving from the lab bench to a freezer decreases the temperature. The particles will move slower, thus collide less often and with less energy. As a result the number of successful collisions decreases, thus rate decreases.

**0.5 mark** for the effect on rate, **0.5 mark** for explanation of decrease in number of successful collisions

**Common Errors and Misconceptions:**

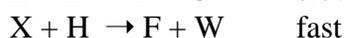
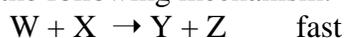
- 1) Students do not use increase or decrease in collisions to explain. In the case of (i) it would simply be explained as surface area has increased, thus rate will increase. In the case of (ii) it would be simply explained as temperature has decreased, thus the rate will decrease.
- 2) Students often inappropriately apply equilibrium concepts; talk about shifts left or right.

**Notes:**

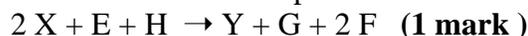
- 1) Students could use the terms “successful” collision or “effective” collisions interchangeably. Students may also define this concept as collisions with the necessary activation energy and orientation.
- 2) For full marks to be awarded, the connection between successful collisions and reaction rate must be stated. This would be true explaining any rate change using collision theory.

**Concept 1.3: Reaction Mechanism****Issue:** New Concept**Item Example:**

Given the following mechanism:

**1.5 %** a) Determine the overall reaction and its rate.**0.5 %** b) Which species is the reaction intermediate?**1 %** c) Explain the effect on the overall reaction rate if the concentration of E is increased.**Answer with Marking Scheme and Explanation:**

- a) add together all reactants from each step, add together all products from each step, cancel species common in the reactants and products



overall reaction rate will be the same as the rate determining step

overall rxn rate: slow **(0.5 mark)**

- b) Rxn Intermediate: Z **(0.5 mark)**

- c) Increasing concentration of E will increase the overall reaction rate **(0.5 mark)** because will increase the rate of the slowest step which is the rate determining **(0.5 mark)**.

**Common Errors and Misconceptions:**

- 1) Students confuse differentiating between reaction intermediate and catalyst.
- 2) Students do not apply the concept of rate determining step with concentration change for a mechanism

**Notes:**

- 1) Many different questions can be asked from the stem of the item example:
  - a) Distinguish between a reaction intermediate and a catalyst using the mechanism above.
  - b) Draw one possible potential energy diagram for the mechanism.

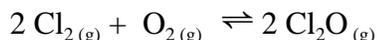
- c) Explain why increasing the concentration of reactant “X” has a negligible effect on the overall reaction rate.

**Concept 1.4:** Equilibrium & Le Chatelier

**Issue:** Predictions about equilibrium use Le Chatelier; explaining equilibrium use rates!

**Item Example:**

- (1%) Predict which direction the following equilibrium would shift as a result of adding O<sub>2</sub>. Justify your answer.

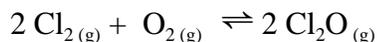


**Answer with Marking Scheme and Explanation:**

Le Chatelier predicts the equilibrium will oppose the change and shift to decrease the concentration of O<sub>2</sub> (**0.5 mark**); shift right (**0.5 mark**)

**Anidated Question & Answer:**

- Q. Explain the effect of adding O<sub>2</sub> on the following equilibrium.



- A. The forward reaction rate will increase as a result of more particle collisions (**0.5 mark**); as more product forms the reverse rate will also increase until a new equilibrium position is established. (**0.5 mark**)

**Common Errors and Misconceptions:**

- 1) Students explain as a rate problem and ignore direction of shift.
- 2) Students confuse direction of shift; statements opposite of what they should be.

**Notes:**

- 1) Teachers should emphasize that questions which ask to *predict* direction of equilibrium shift should use Le Chatelier’s Principle; questions which ask to *explain* direction of equilibrium shift should use rates.
- 2) Teachers should note that in describing the change in the equilibrium the following phrases are acceptable:
  - shifts to the ‘right’
  - favors ‘right’ side
  - ‘forward’ reaction favored
  - ‘products’ favored

**Concept 1.5: Equilibrium Calculations****Issue:** Procedure for Solving Equilibrium Problems Involving Initial Concentrations**Item Example:** June 2004 Sample Problems #13 on Page 3**5%** When 3.00 mol of ammonia gas is placed in a 2.00 L flask, the equilibrium below is established.

At equilibrium, 0.900 mol of hydrogen gas is present. Calculate the value of K for this equilibrium.

**Answer with Marking Scheme and Explanation:**

The recommended procedure for solving equilibrium problems with initial concentrations is the use of an ICE table.

	$2 \text{NH}_{3(g)} \rightleftharpoons$	$\text{N}_{2(g)} +$	$3 \text{H}_{2(g)}$	$[\text{NH}_3]_{\text{initial}} = \frac{3.00 \text{ mol}}{2.00 \text{ L}}$ $= \mathbf{1.50 \text{ mol/L}}$ $[\text{H}_2]_{\text{eqbm}} = \frac{0.900 \text{ mol}}{2.00 \text{ L}}$ $= \mathbf{0.450 \text{ mol/L}}$ <p><b>(0.5 mark for conc calc)</b></p>
<b>I</b> <sub>initial</sub>	1.50	0	0	
<b>C</b> <sub>hange</sub>	- 2x	+ x	+ 3x	
<b>E</b> <sub>qbm</sub>	1.50 - 2x	x	3x	
	<b>(0.5 mark)</b>	<b>(0.5 mark)</b>	<b>(0.5 mark)</b>	

$$[\text{H}_2]_{\text{eqbm}} = 0.450 \text{ mol/L} = 3x ; \quad \text{thus } x = 0.150 \text{ mol/L} \quad \mathbf{(0.5 \text{ mark})}$$

*(given) (table)*

$$[\text{NH}_3]_{\text{eqbm}} = 1.50 - 2x = 1.50 - 2(0.150) = 1.20 \text{ mol/L} \quad \mathbf{(0.5 \text{ mark})}$$

$$[\text{N}_2]_{\text{eqbm}} = x = 0.150 \text{ mol/L} \quad \mathbf{(0.5 \text{ mark})}$$

$$K = \frac{[\text{N}_2][\text{H}_2]^3}{[\text{NH}_3]^2} = \frac{(0.150)(0.450)^3}{(1.20)^2} = 9.48 \times 10^{-3} \quad \text{(since units for K are variable they are often omitted)}$$

**(0.5 mark) (0.5 mark) (0.5 mark)**

**Common Errors and Misconceptions:**

1. Students forget to convert moles to concentration.\
2. Student arrive at the 'x' value incorrectly when the ratio is not 1:1:1
3. Students make mistakes when calculating the numerical value of K; often forget to square or cube a number.

**Notes:**

1. The ICE table is the recommended procedure, but there are other acceptable methods.
2. Concentration or mole values may be used in the ICE table, however if moles are used they must be converted to concentration before plugging into the K expression.
3. For full value, the K expression must be shown.
4. Another version of this question would involve initial concentration and percent reaction.

## Unit 2

### Concept 2.1 : Acid-Base Equilibrium

**Issue:** pH of weak acids or weak bases - solving the quadratic.

#### Item Example:

**4%** Calculate the pH of a 0.15 M solution of nitrous acid.  $K_a(\text{HNO}_2) = 5.6 \times 10^{-3}$

#### Answer with Marking Scheme and Explanation:

Recommended method of solving weak acid or weak base problems is to set up an ICE table.

	$\text{HNO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons$	$\text{NO}_2^-(\text{aq}) +$	$\text{H}_3\text{O}^+(\text{aq})$
<b>I</b> <sub>initial</sub>	0.15	0	~ 0
<b>C</b> <sub>hange</sub>	- x	+ x	+ x
<b>E</b> <sub>qbm</sub>	0.15 - x (0.5 mark)	x	x (0.5 mark)

aside: The thought process for students at this point is recognition that they want pH, thus they need the  $[\text{H}_3\text{O}^+]_{\text{eqbm}} = x$

$$K_a = \frac{[\text{NO}_2^-][\text{H}_3\text{O}^+]}{[\text{HNO}_2]} \quad 5.6 \times 10^{-3} = \frac{\chi^2}{(0.15 - \chi)}$$

(0.5 mark) (0.5 mark)

aside: At is usually at this point where students see they may have to solve a quadratic; to determine **IF** the quadratic is needed students may do the following calculation check

$$\frac{[\text{acid}]_{\text{initial}}}{K_a} = \frac{0.15}{5.6 \times 10^{-3}} = 27 < 500 \text{ thus quadratic must be solved}$$

$$\chi^2 + 5.6 \times 10^{-3} \chi - 8.4 \times 10^{-4} = 0 \quad (0.5 \text{ mark})$$

$$\chi = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a} = \frac{5.6 \times 10^{-3} \pm \sqrt{(5.6 \times 10^{-3})^2 - (4 \times 1 \times -8.4 \times 10^{-4})}}{2 \times 1} \quad (0.5 \text{ mark})$$

$$\chi = 0.031 = [\text{H}_3\text{O}^+] \quad (0.5 \text{ mark}) \quad (\text{or } -0.026 ; \text{ not necessary, concentration cannot be negative})$$

$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log 0.031 = 1.50 \quad (0.5 \text{ mark})$$



**aside:** It is usually at this point where students see they may have to solve a quadratic; to determine **IF** the quadratic is needed students may do the following calculation check

$$\frac{[\text{acid}]_{\text{initial}}}{K_a} = \frac{0.15}{6.2 \times 10^{-10}} > 500 \quad \text{since the answer is } > 500 \text{ the quadratic } \mathbf{\text{need not}} \text{ be solved}$$

**(0.5 mark)**

Student **must state assumption** if not solving the quadratic

$$\text{Assume } 0.15 - \chi \sim 0.15 \quad \mathbf{(0.5 \text{ mark})}$$

$$6.2 \times 10^{-10} = \frac{\chi^2}{0.15}$$

$$\chi = \sqrt{(6.2 \times 10^{-10})(0.15)} = 9.6(4) \times 10^{-6} \text{ M} = [\text{H}_3\text{O}^+] \quad \mathbf{(0.5 \text{ mark})}$$

(4) is an extra digit more than is significant; carried over into the next calculation

$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log 9.6(4) \times 10^{-6} = 5.02$$

### Common Errors and Misconceptions:

1. Teachers should note that because of the limitations placed on K values in the old curriculum it was not required students state assumption and do a check of the assumption.

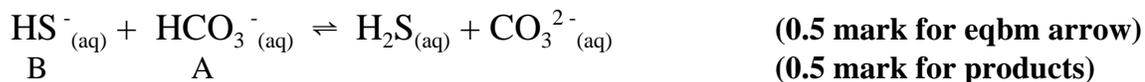
### Notes:

1. p. 66 of the interim curriculum guide need to be changed from 100 times to 500 times for the check
2. Students may solve the quadratic if they wish; if they do the mark for the calculation check and stating assumption is then awarded to set up of the quadratic.
3. Some students may check their assumption after they solve for ' $\chi$ ' by doing the 5% rule:  
$$\% \text{ rxn} = \left( \frac{[\ ]_{\text{change}}}{[\ ]_{\text{initial}}} \right) \times 100\% = \left( \frac{9.6(4) \times 10^{-6}}{0.15} \right) \times 100\% = 6.4 \times 10^{-3}\% < 5\% \quad (\text{assumption good})$$
3. Rounding to the correct number of significant figures should be done in the final reported answer. A **minimum** of one digit more than is significant; ie: 0.031(9) should be carried through each calculation done before the final calculation.

**Concept 2.3:** Predicting Products of Weak Acid - Weak Base Reactions**Issue:** New Concept**Item Example:****2%** Determine the acid-base neutralization reaction between a solution of NaHS and  $\text{KHCO}_3$ **Answer with Marking Scheme and Explanation:**

neutral	A/B	neutral	A/B	A/B	
---------	-----	---------	-----	-----	--

Stronger Base	Stronger Acid	<b>(0.5 mark)</b>
------------------	------------------	-------------------

**Common Errors and Misconceptions:**

1) Students treat this as a double replacement reaction. They do not recognize ions acting as acids and bases.

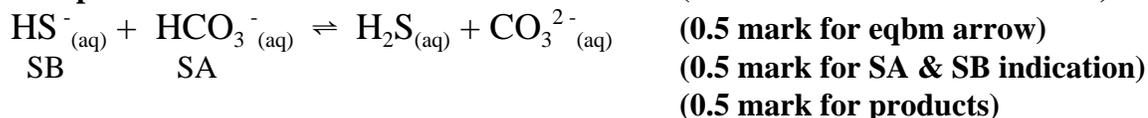


2) Ion charges are often omitted thus resulting in loss of marks.

3) Incorrect hydrogen transfer; students do not recognize the need to use the Strength Table to identify the stronger acid and/or base.

**Notes:**

1) The identification of the stronger acid and the stronger base is the key. Students may simply react these without showing other species, but indication of which is the acid and which is the base is necessary.

**Acceptable Answer:**

## Unit 3

### Concept 3.1: Calorimetry

Issue: New Problem Type

#### Item Example:

**2%** A coffee-cup calorimeter contains 125 g of coffee at 95.2°C has a specific heat of 4.35 J/g°C. If 22 g of fresh milk at 5.0 °C with a specific heat of 4.54 J/g°C is added, what will be the final temperature of the mixture?

#### Answer with Marking Scheme and Explanation:

$$q_{\text{lost}} + q_{\text{gained}} = 0$$

$$q_{\text{lost}} = -q_{\text{gained}}$$

$$q_{\text{coffee}} = -q_{\text{milk}}$$

$$m_c c_c \Delta T_c = - (m_m c_m \Delta T_m)$$

$$(125 \text{ g}) (4.35 \text{ J/g}^\circ\text{C}) (T_f - 95.2^\circ\text{C}) = - (22 \text{ g}) (4.54 \text{ J/g}^\circ\text{C}) (T_f - 5.0^\circ\text{C})$$

$$T_f = 81.2^\circ\text{C}$$

**0.5 mark for indication: q (lost by coffee) = q (gained by milk)**

**0.5 mark for indication of sign**

**0.5 mark for info into formula**

**0.5 mark for answer**

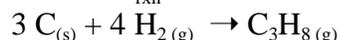
#### Common Errors and Misconceptions:

- 1) Students forget the negative sign
- 2) Mathematical manipulation giving the wrong answer.

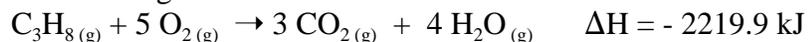
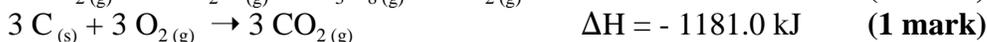
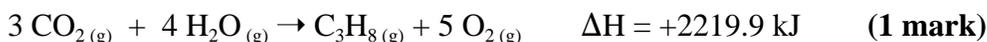
#### Notes:

- 1) There are many ways to vary this answer: ie: given all variables
  - except  $T_i$  for one substance
  - except  $c$  for a substance
  - except  $m$  for a substance



**Concept 3.3:** Using Hess's Law**Issue:** Reaction equations and their manipulation must be shown.**Item Example:****4%** Calculate the  $\Delta H_{\text{rxn}}$  for the following reaction:

Given the following information:

**Answer with Marking Scheme and Explanation:**

adding equations and cancelling out common terms gives

**(0.5 mark for equation manipulation, 0.5 mark for each calculated  $\Delta H$  value)****Common Errors and Misconceptions:**

- 1) Generally this type of question is done well, however students do make mistakes in the addition of  $\Delta H$  values.

**Notes:**

- 1) In doing this type of problem students *must*:
  - i) show the new *manipulated* equations to get the overall equation; ie: show those equations reversed with the appropriate  $\Delta H$  value and sign, show those equations multiplied by some factor with the appropriate  $\Delta H$  value and sign
  - ii) show cancelling of terms so as to "see" the overall reaction.

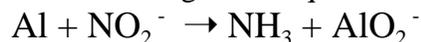
## Unit 4

### Concept 4.1: Balancing Redox Equations

Issue: Electrochemistry - New Unit

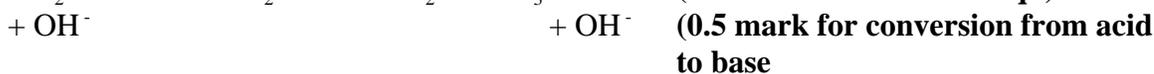
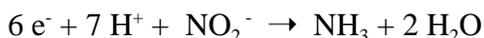
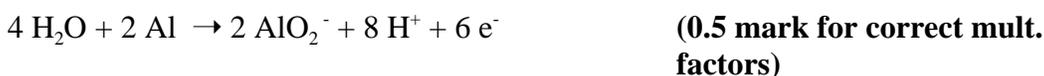
#### Item Example:

3% Balance the following redox equation under basic conditions



#### Answer with Marking Scheme and Explanation:

One method of balancing redox equations is using the half-reaction method.



#### Notes:

- 1) The method used here:
  - i) students balance as if under acidic conditions (see sample problem on page 737-738 of MHR text)
  - ii) to change to basic conditions, add the same number of  $\text{OH}^-$  ions as  $\text{H}^+$  ions to both sides of the equation
  - iii) combine  $\text{H}^+$  ions and  $\text{OH}^-$  ions into  $\text{H}_2\text{O}$
  - iv) remove  $\text{H}_2\text{O}$  molecules present on both sides of the equation.
- 2) An alternate method would be the oxidation number method on sampled on page 747-748 of text.
- 3) Students will not be asked to balance using a specified method.

**Concept 4.2:** Electrochemical Cells  
**Issue:** Electrochemistry - New Unit

**Item Example:**

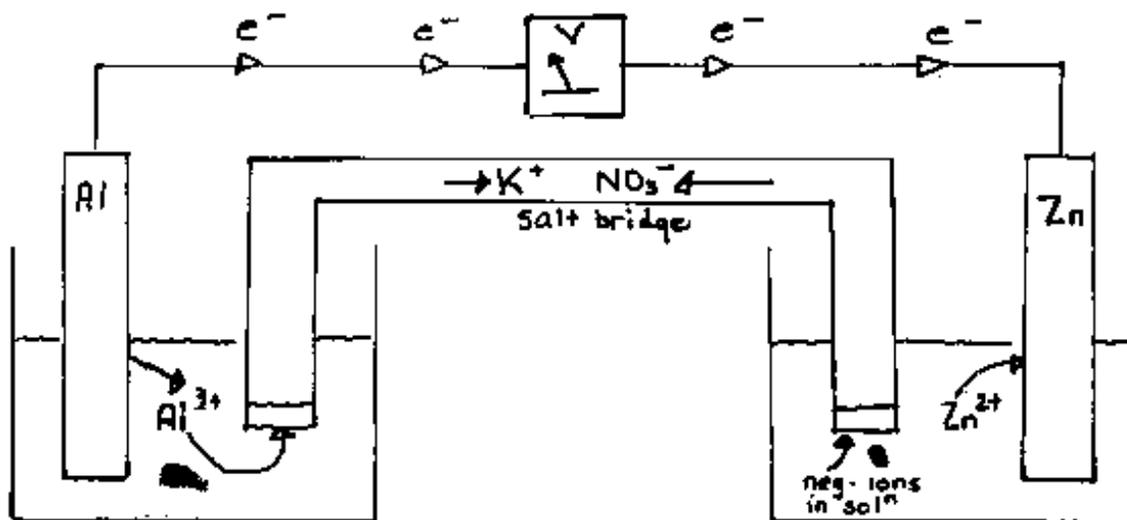
**4%** Given the following cell notation:  $\text{Al}_{(s)} | \text{Al}^{3+}_{(aq)} || \text{Zn}^{2+}_{(aq)} | \text{Zn}_{(s)}$

- a) Draw and label the electrochemical cell by identifying
- i) the anode and cathode (1.0 mark)
  - ii) the oxidation and reduction half-reactions (1.0 mark)
  - iii) the direction of electron and ion flow (1.0 mark)
- b) Calculate the net voltage for this cell. Is the cell spontaneous? (1.0 mark)

**Answer with Marking Scheme and Explanation:**

anode oxidation half-rxn: $\text{Al} \rightarrow \text{Al}^{3+} + 3 e^{-}$	cathode reduction half-rxn: $\text{Zn}^{2+} + 2 e^{-} \rightarrow \text{Zn}$
--	--

b) net cell voltage:  $\text{Al} \rightarrow \text{Al}^{3+} + 3 e^{-}$   $E^{\circ} = + 1.66 \text{ V}$



$$E^{\circ} = - 0.76 \text{ V}$$

$$E^{\circ}_{\text{cell}} = +0.90 \text{ V}$$

spontaneous

**Common Mistakes and Misconceptions:**

- Reversing the following which results in the cell being drawn incorrectly:
  - Cell notation convention: anode/anodic ion sol<sup>n</sup>//cathodic ion sol<sup>m</sup>/cathode
  - anode - oxidation - loss of electrons / cathode - reduction - gain of electrons
- Multiplying E° values by the multiplication factor to balance electrons (as would be done with ΔH values using Hess's Law)
- Not changing the sign on E° values when half-reaction is reversed.
- Simply adding E° values to arrive at overall E° for the cell.

**Notes:**

- Alternate styles of questions could be:
  - A cell diagram is given which would require proper labeling and statement of overall reaction.
  - Given the identity of one electrode and the net cell voltage; identify the second electrode.

**Concept 4.3:** Electrolysis**Issue:** Electrochemistry - New Unit**Item Example:**

**3%** If 20.0 A of current flows through an electrolytic cell containing molten aluminum oxide for 1.00 h, what mass of aluminum will be deposited at the cathode?

**Answer with Marking Scheme and Explanation:**

Students should



Change time to seconds

$$t = 1.00 \text{ h} \times 3600 \text{ s/h} = 360(0) \text{ s} \quad \text{(0.5 mark)}$$

Calculate quantity (Q) of electric charge

$$Q = I * t = (20.0 \text{ A}) (360(0)\text{s}) = 720(0) \text{ C} \quad \text{(0.5 mark)}$$

Calculate moles of electrons transferred

$$n \text{ of } e^{-} = Q / F = (720(0)\text{C} / 96500 \text{ C/mol } e^{-}) = 0.0746(1) \text{ mol } e^{-} \quad \text{(0.5 mark)}$$

Calculate moles of Al using equation

$$n \text{ of Al} = 0.0746(1) \text{ mol } e^{-} \times \frac{1 \text{ mol Al}}{3 \text{ mol } e^{-}} = 0.0248(7) \text{ mol} \quad \text{(0.5 mark)}$$

Calculate mass of Al

$$m \text{ of Al} = n \times M = (0.0746(1)) (26.98 \text{ g/mol}) = 0.671 \text{ g} \quad \text{(0.5 mark)}$$

**Common Mistakes and Misconceptions:**

- Students often know that to find mass of Al they need moles, but jump to using  $n = Q/F$ . They do not make the connection between moles of electrons transferred and moles of Al produced.
- Students will often complete as if the ratio between electrons and Al is 1 : 1. They need to make the connection that molten  $\text{Al}_2\text{O}_3$  is  $\text{Al}^{3+}$  and  $\text{O}^{2-}$  and that it is the  $\text{Al}^{3+}$  that is reduced to Al; correct number of electrons must be used to balance the charge.

**Notes:**

1. Rounding to the correct number of significant figures should be done in the final reported answer. A **minimum** of one digit more than is significant (shown in brackets) should be carried through each calculation done before the final calculation.
2. Alternate styles of questions could be:
  - i) how long a certain current is run to produce a desired mass.
  - ii) what is the average current during a given time to produce a desired mass.

**Concept 4.4:** Redox Stoichiometry**Issue:** Electrochemistry - New Unit

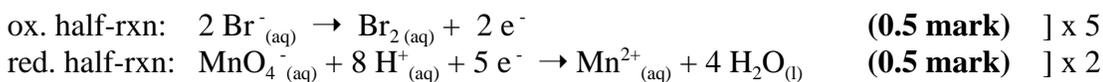
Students must use redox tables, then properly balance the redox reaction so the appropriate stoichiometry can be applied.

**Item Example:**

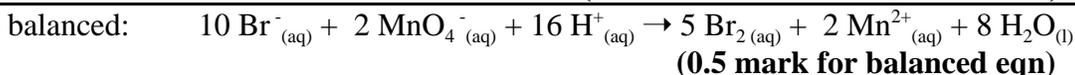
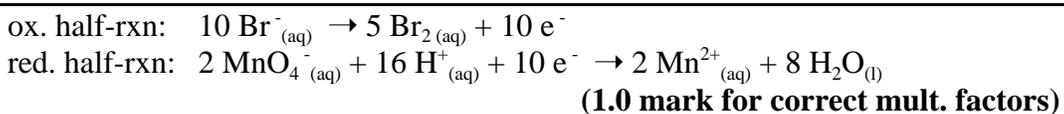
**4%** In a titration, 25.0 mL of  $\text{Br}^-_{(\text{aq})}$  was oxidized to  $\text{Br}_{2(\text{aq})}$  by 0.200 mol/L  $\text{KMnO}_{4(\text{aq})}$  in acid solution. If 15.0 mL of  $\text{KMnO}_{4(\text{aq})}$  was required what is the concentration of  $\text{Br}^-_{(\text{aq})}$ ?

**Answer with Marking Scheme and Explanation:**

Students must balance the redox reaction:



- aside: 1) In problem students are told  $\text{Br}^-$  is oxidized to  $\text{Br}_2$ .
- 2) Students must recognize  $\text{K}^+$  as a spectator and that is  $\text{MnO}_4^-$  that is being reduced.
- 3) Students must then use redox tables to predict reduction half reaction for  $\text{MnO}_4^-$  under acidic conditions.



Students can now use stoichiometry to find  $[\text{Br}^-]$ :

$$n(\text{MnO}_4^-) = c * v = (0.200 \text{ mol/L}) (0.0150 \text{ L}) = 0.00300 \text{ mol} \quad \text{(0.5 mark)}$$

$$n(\text{Br}^-) = 0.0300 \text{ mol MnO}_4^- \times (10 \text{ mol Br}^- / 2 \text{ mol MnO}_4^-) = 0.150 \text{ mol} \quad \text{(0.5 mark)}$$

$$c(\text{Br}^-) = n / v = 0.150 \text{ mol} / 0.0250 \text{ L} = 6.00 \text{ mol/L} \quad \text{(0.5 mark)}$$

**Common Mistakes and Misconceptions:**

1. Overall balancing of equation done incorrectly resulting in wrong molar coefficients.

**Notes:**

1. If “oxidized” was **NOT** in the question and the word “reacts” was used instead students may attempt to balance the equation as a double replacement reaction.
2. Students must be able to use redox tables to identify strong oxidizing and reducing agents and thus predict reaction if not told what is being oxidized or reduced.