STAWA
SCIENCE TEACHERS' ASSOCIATION
OF WESTERN AUSTRALIA

CHEMISTRY
2007 TEE SOLUTIONS*

*THESE SOLUTIONS ARE NOT A MARKING KEY.
THEY ARE A GUIDE TO THE POSSIBLE ANSWERS
AT A DEPTH THAT MIGHT BE EXPECTED
OF YEAR 12 STUDENTS. IT IS UNLIKELY
THAT ALL POSSIBLE ANSWERS TO THE QUESTIONS
ARE COVERED IN THESE SOLUTIONS.

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Leadership in Science Education

CHEMISTRY

Tertiary Entrance Examination 2007 Solutions

PART 1: MULTIPLE CHOICE (60 Marks)

1	a	6	b	11	b	16	b	21	c	26	d
2	b	7	c	12	b	17	d	22	a	27	d
3	a	8	b	13	c	18	d	23	c	28	a
4	c	9	c	14	c	19	d	24	a	29	c
5	a	10	b	15	b	20	a	25	a	30	c

PART 2: SHORT ANSWER (70 Marks)

1. *1 mark is deducted for each error in the equation. While state symbols are not required for full marks they are useful for working out observations. The bulk of the observations must be provided for the full mark. Observations in square brackets are acceptable alternatives to the observations given.*

   (a) $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ (2 marks)
   White smoke [fume] appears   (1 mark)

   (b) $3Zn(s) + 2Au^{3+}(aq) \rightarrow 3Zn^{2+}(aq) + 2Au(s)$ (2 marks)
   Yellow [golden or dark coloured] solid forms, [silver solid dissolves]   (1 mark)

   (c) $Ag_2O(s) + 4NH_3(aq) + H_2O(l) \rightarrow 2[Ag(NH_3)_2]^+(aq) + 2OH^-(aq)$ (2 marks)
   Dark coloured [white] solid dissolves to form colourless solution   (1 mark)

   (d) No reaction   (2 marks)
   No changes   (1 mark)
   (For full marks, both 'no reaction' and 'no changes' are required)

2. 2 marks for each structure. Marks are deducted for missing brackets, charge and no bonding pairs of electrons.

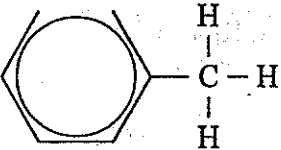 | Ethanol | |
   |---|---|
   | | H H H
     \| \| \|
H — C — C — O:
     \| \|
     H   H |
   | Potassium hydroxide | [K⁺] [:Ö — H]⁻ |

   (4 marks)

3. Dispersion forces   (1 mark)
   Dispersion forces arise due to the attraction of electrons to temporary dipoles of adjacent molecules. Each nitrogen molecule has a small number of electrons, therefore the dispersion forces between nitrogen molecules are small. Small dispersion forces are only strong enough to hold molecules together in the solid state at low temperatures. The greater molecular kinetic energy at high temperatures is sufficient to overcome the dispersion forces and result in a phase change.
   (3 marks)

4.   *There is more than one possible answer for (a)*

H H H H | | | | H $-$ C $-$ C $-$ C $-$ N | | | | H H H H	Propanamine
$\begin{array}{c} \quad H-O \\ H \quad\mid \quad\quad H \\ \mid \quad\quad\mid \quad\quad\mid \\ H-C-C-C-H \\ \mid \quad\quad\mid \quad\quad\mid \\ H \quad H-C-H \quad H \\ \quad\quad\mid \\ \quad\quad H \end{array}$	2-methyl-propan-2-ol [2-methyl-2-propanol]
$\begin{array}{c} H \\ \mid \\ -C-H \\ \mid \\ H \end{array}$	Methylbenzene [toluene]

1 mark for each name and 1 mark for each structure.   (6 marks)

5.   (a)   3 moles of H_2 are consumed for each mole of N_2 consumed.   (1 mark)

(b)   The reaction has reached equilibrium   (1 mark)

(c)   More N_2 is added to the system.   (1 mark)

(d)   i)   The forward reaction rate is increased.   (1 mark)
ii)   The reverse reaction rate is increased.   (1 mark)

(e)   More N_2 molecules are added to the system, therefore there is greater rate of collision of N_2 molecules with H_2 molecules, which results in a greater reaction rate.   (2 marks)
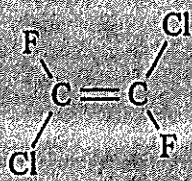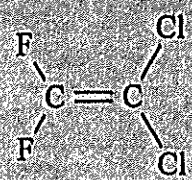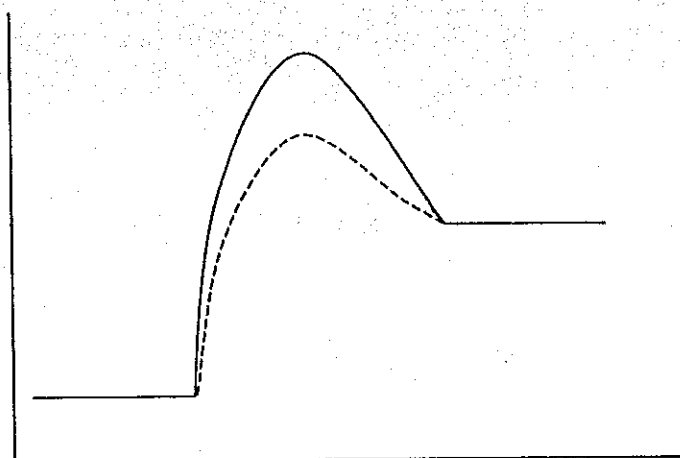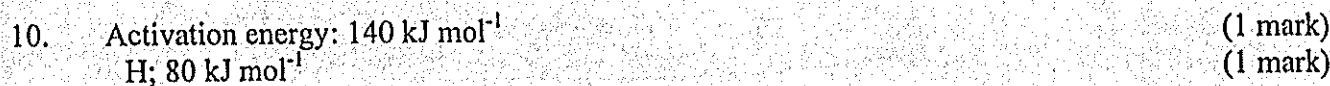
(f)
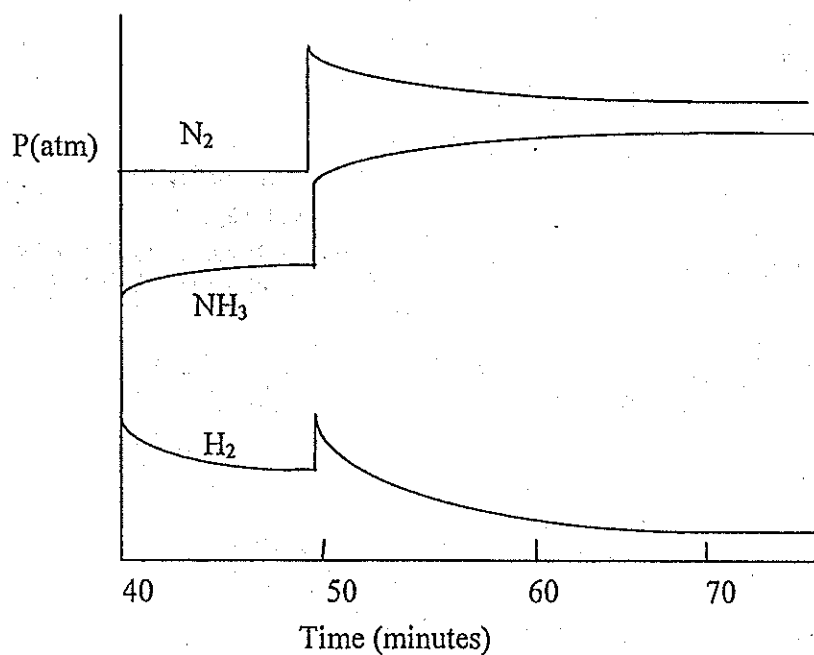
6.

	Rate of forward reaction	Equilibrium yield of Cu^{2+} (aq)
HCl (g) is passed into the solution	Increases	Increases
$CuSO_4$ solution is added	No change	Decreases
More finely powdered CuS is added	Increases	No change

Note: Effect on rate is intended to be at the instant of change, not as equilibrium is re-established.

(6 marks)

7.

	Trans-1,2-dichloro-1,2-difluoroethene
	1,1-dichloro-2,2-difluoroethene

(4 marks)

8. (a) $HSO_5^-(aq) + 2H^+(aq) + 2e^- \rightleftharpoons HSO_4^-(aq) + H_2O(l)$ (1 mark)

(b) $CH_3CH_2CH_2OH(l) + H_2O(l) \rightleftharpoons CH_3CH_2COOH(aq) + 4H^+(aq) + 4e^-$ (2 marks)

(c) $CH_3CH_2CH_2OH(l) + 2HSO_5^-(aq) \rightleftharpoons CH_3CH_2COOH(aq) + 2HSO_4^-(aq) + H_2O(l)$ (2 marks)

9. (a) silver, zinc, cadmium, scandium, yttrium, lanthanum(any two accepted) (2 marks)

(b) hydrogen, carbon, nitrogen, oxygen, phosphorus, sulfur, chlorine, arsenic, selenium, bromine, tin, antimony, tellurium, iodine, lead. (any two accepted) (2 marks)

10. Activation energy: 140 kJ mol^{-1} (1 mark)
   H; 80 kJ mol^{-1} (1 mark)

*1 mark for lower activation energy*
1 mark for same energy for reactants and products.

11. (a) $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$
Or
$2NaCl(s) + H_2SO_4(l) \rightarrow NaHSO_4 + HCl(g)$ (1 mark)

(b) Water droplets have a higher surface area so produce a faster rate of reaction, heat of reaction is dissipated more readily.   (2 marks)

(c) cleaning brickwork
pH adjustment in swimming pools
laboratory reagent
(any other sensible use)   (any two for 2 marks)

12. X: alcohol
Y: carboxylic acid
Z: amine

    (3 marks)

13.
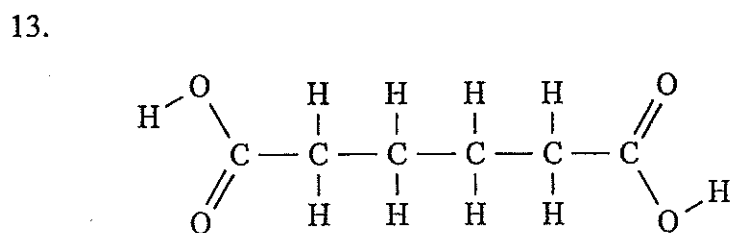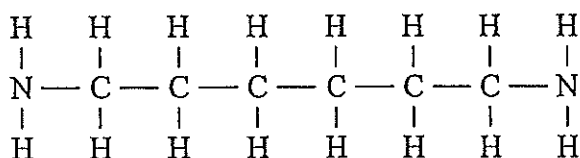
    (1 mark)

    (1 mark)

Condensation   (1 mark)

PART 3: CALCULATIONS (50 Marks)

1 mark is deducted per question for inappropriate number of significant figures in final answers.

1. (a) $[Au(CN)_2]^- + e^- \rightarrow Au + 2CN^-$ (1 mark)

(b) $Q = I \times t$
$= 30 \times 24 \times 60 \times 60$
$= 2.592 \times 10^6 \text{ C}$

$n(e^-) = \dfrac{Q}{F}$

$= \dfrac{2.592 \times 10^6}{9.649 \times 10^4}$

$= 26.86 \text{ mol}$

$n(Au) = n(e^-) \times 0.97$
$= 26.86 \times 0.97$

$$= 26.06 \text{ mol}$$
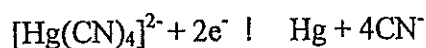
$$\begin{aligned} m(Au) &= n(Au) \times 197.0 \\ &= 26.06 \times 197.0 \\ &= 5.13 \times 10^3 \text{ g} \end{aligned}$$

(4 marks)

(c)   *Two correct answers were accepted for this question.*

Assuming same efficiency for Hg and Au

$$\begin{aligned} n(Au) &= \frac{m(Au)}{197.0} \\ &= \frac{1000}{197.0} \\ &= 5.076 \text{ mol} \end{aligned}$$

$$\begin{aligned} n(e^-) &= n(Au) \\ &= 5.076 \text{ mol} \end{aligned}$$

$$[Hg(CN)_4]^{2-} + 2e^- \rightarrow Hg + 4CN^-$$

$$\begin{aligned} n(Hg) &= \frac{1}{2} \times n(e^-) \\ &= \frac{1}{2} \times 5.076 \\ &= 2.538 \text{ mol} \end{aligned}$$

$$\begin{aligned} m(Hg) &= 2.538 \times 200.6 \\ &= 509 \text{ g} \end{aligned}$$

OR
Assuming 100% efficiency for Hg

$$n(Au) = n(e^-) \times 0.97, \text{ so } n(e^-) = \frac{5.076}{0.97}$$
$$= 5.233 \text{ mol}$$

$$\begin{aligned} n(Hg) &= \frac{1}{2} \times 5.233 \\ &= 2.616 \text{ mol} \end{aligned}$$
$$\begin{aligned} m(Hg) &= 2.616 \times 200.6 \\ &= 525 \text{ g} \end{aligned}$$

(4 marks)

2.   (a) $4CH_3NO_2(l) + 3O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g) + 2N_2(g)$ (2 marks)
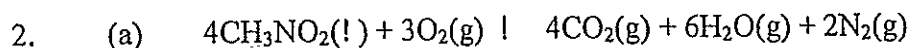
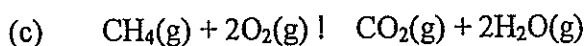(b) $$n(CH_3NO_2) = \frac{1000}{61.044 \text{ g mol}^{-1}}$$
$$= 16.38 \text{ mol}$$

$$\begin{aligned} n(O_2) &= 0.75 \times 16.38 \\ &= 12.29 \text{ mol} \end{aligned}$$

$$V(O_2 \text{ at STP}) = 12.29 \times 22.41$$
$$= 275.3 \text{ L}$$

$$V(O_2 \text{ at } 25°C) = \frac{275.3 \times 298}{273}$$
$$= 300.6 \text{ L}$$

$$V(\text{air}) = \frac{100}{20} \times 300.6$$
$$= 1.50 \times 10^3 \text{ L}$$

(3 marks)

(c) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

$$n(CH_4) = \frac{1000}{16.042 \text{ g mol}^{-1}}$$
$$= 62.37 \text{ mol}$$
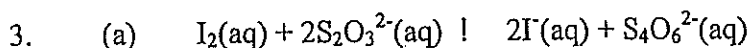
$$V(O_2) = 62.37 \times 22.41 \times \frac{298}{273}$$
$$= 3051 \text{L}$$

$$V(\text{air}) = \frac{100}{20} \times 3051$$
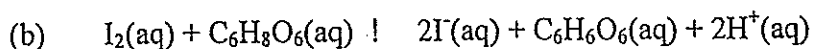$$= 1.53 \times 10^4 \text{ L}$$

(3 marks)

(d) Combustion of methane requires much more air compared to the same mass of nitromethane.

(1 mark)

3. (a) $I_2(aq) + 2S_2O_3{}^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6{}^{2-}(aq)$

(1 mark)

(b) $I_2(aq) + C_6H_8O_6(aq) \rightarrow 2I^-(aq) + C_6H_6O_6(aq) + 2H^+(aq)$

(1 mark)

(c) $n(I_2)$ added $= 0.0521 \times 0.100$
$$= 5.21 \times 10^{-3} \text{ mol}$$

$$(\text{average titre } S_2O_3{}^{2-} \text{ (aq), excluding first (rough) value}) = \frac{13.96 + 13.78 + 13.92}{3}$$
$$= 13.89 \text{mL}$$

$n(S_2O_3{}^{2-}(aq)$ reacting with 20.0 mL of solution) $= 0.0493 \times 0.01389$
$$= 6.846 \times 10^{-4} \text{ mol}$$

$n(S_2O_3{}^{2-}$ (aq) required for 250.0 mL of solution) $= \frac{250.0}{20.0} \times 6.846 \times 10^{-4}$
$$= 8.558 \times 10^{-3} \text{ mol}$$

$n(I_2$ remaining in 250 mL) $= \frac{1}{2} \times n (S_2O_3{}^{2-}$ (aq))
$$= \frac{1}{2} \times 8.558 \times 10^{-3}$$
$$= 4.279 \times 10^{-3} \text{ mol}$$

$$n(I_2 \text{ consumed}) = n(I_2 \text{ added}) - n(I_2 \text{ remaining})$$
$$= 5.21 \times 10^{-3} - 4.279 \times 10^{-3}$$
$$= 9.312 \times 10^{-4} \text{ mol}$$

$$n(C_6H_8O_6) = n(I_2)$$
$$= 9.312 \times 10^{-4} \text{ mol}$$

$$m(C_6H_8O_6) = 9.312 \times 10^{-4} \times 176.124$$
$$= 0.164 \text{ g}$$

(8 marks)

(d)

$$\% \, C_6H_8O_6 = \frac{0.164}{0.250} \times 100$$
$$= 65.5\%$$

(1 mark)

4. (a) In 3.00 g of jarosite
$$n(K) = 0.0622 \times 0.250$$
$$= 0.01555 \text{ mol}$$
$$m(K) = 0.01555 \times 39.10$$
$$= 0.608 \text{ g}$$

$$n(MnO_4^- \text{ reacting with 25.0 mL solution}) = 0.0108 \times 0.0288$$
$$= 3.110 \times 10^{-4} \text{ mol}$$

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$
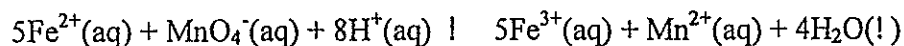
$$n(Fe) = 5 \times n(MnO_4^-)$$
$$= 5 \times 3.115 \times 10^{-4}$$
$$= 1.555 \times 10^{-3} \text{ mol}$$

$$n(Fe \text{ in 250 mL of solution [3.00 g of jarosite]}) = \frac{250}{25} \times 1.555 \times 10^{13}$$
$$= 1.555 \times 10^{-2} \text{ mol}$$

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$
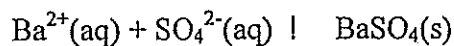
$$n(SO_4^{2-} \text{ in 100 mL}) = n(BaSO_4(s))$$
$$= \frac{0.967}{233.36 \, g \, mol^{11}}$$
$$= 4.144 \times 10^{-3} \text{ mol}$$

$$n(SO_4^{2-} \text{ in 250 mL [3.00 g of jarosite]}) = \frac{250}{100} \times 4.144 \times 10^{13}$$
$$= 1.036 \times 10^{-2} \text{ mol}$$

$$m(SO_4^{2-}) = 1.036 \times 10^{-2} \times 96.06$$
$$= 0.9952 \text{ g}$$

$$m(OH^-) = 3.00 - (0.6080 + 0.8685 + 0.9952)$$
$$= 0.528 \text{ g}$$

$$n(OH^-) = \frac{0.528}{17.008}$$

$$= 3.104 \times 10^{-2} \text{ mol}$$

	K	Fe	SO_4^{2-}	OH
n	0.01555	0.01555	0.01036	0.03104
Ratio	$\dfrac{0.01555}{0.01036}$	$\dfrac{0.01555}{0.01036}$	$\dfrac{0.01036}{0.01036}$	$\dfrac{0.03104}{0.01036}$
	= 1.5	= 1.5	= 1	= 2.99
Round	3	3	2	6

The empirical formula is thus $K_3Fe_3(SO_4)_2(OH)_6$
(This question could also be done by calculating percentages of each component)

(12 marks)

5. (a) $n(Fe^{2+}(aq))$ $= 0.00122 \times 2.00$
$= 0.00244 \text{ mol}$ (1 mark)

(b) $n(Fe^{3+}(aq))$ $= n(Fe^{2+}(aq))$
$= 0.00244 \text{ mol}$ (1 mark)

(c) $n(Fe(OH)_3(s)) = n(Fe^{3+}(aq))$
$= 0.00244 \text{ mol}$ (1 mark)

(d) $m(Fe(OH)_3) = 0.00244 \times 106.874$
$= 0.2608 \text{ g}$ (1 mark)

(e) $m(Cr(OH)_3) = $ total mass of precipitate $- m(Fe(OH)_3)$
$= 2.67 - 0.2608$
$= 2.41 \text{ g}$ (1 mark)

(f)
$$m(Cr) = \frac{M(Cr)}{M(Cr(OH)_3)} \times m(Cr(OH)_3)$$
$$= \frac{52}{103.024} \times 2.41$$ (2 marks)
$$= 1.22 \text{g}$$

(g)
$$\text{Cr in soil} = \frac{m(Cr)}{m(soil)} \times 10^6$$
$$= \frac{1.22}{2160} \times 10^6$$ (2 marks)
$$= 56.3 \text{ ppm}$$

PART 4: EXTENDED RESPONSE (20 marks)

In general for full marks an essay should be a minimum of 1 ! to 2 pages and
- *Demonstrate sound understanding of chemistry*
- *On the topic given*
- *Written in reasonable English*
- *With some reasoning shown*
- *With a beginning, middle and end*
- *Either no errors, or errors which are trivial.*

The key steps in the procedure for determining the percentage of iron are given below. Variation in the order is acceptable but your answer should demonstrate a logical order. The answer did not require example calculations. For full marks explanation of reasons for various steps was required. Just a list or laboratory procedure is not considered a sufficient response. Diagrams could be included. Equations must be included.

1.   Prepare a primary standard solution from oxalic acid dihydrate by weighing out an accurately known mass of the acid, dissolving it in deionised water in a beaker, transferring it to a volumetric flask and making it up to the mark. (*Due to the nature of the photograph, any reasonable volume could have been used, e.g. 250 mL for the volumetric flask*). The beaker should be rinsed with deionised water several times and the rinsings transferred to the volumetric flask to maximise the amount of oxalic acid dihydrate transferred. *A discussion of the characteristics of a primary standard is not essential but adds to the quality of the answer.* A target concentration of 0.05 mol L^{-1} would be appropriate. The $KMnO_4$ cannot be used as a primary standard because it cannot be obtained in a pure form, and its solutions oxidise slowly over time.

2.   Standardise the 0.02 mol L^{-1} $KMnO_4$ solution (the solution provided could be used or prepared from the $KMnO_4$ solid available. If starting with the solid, the method for preparing the solution is required, such as dissolving a sufficient quantity of $KMnO_4$ solid to produced an approximately 0.02 mol L^{-1} solution, heating and filtering it to remove solid impurities.). *Details of the procedure should be provided. A diagram could be included here but is not necessary.* The $KMnO_4$ solution is placed in the burette after rinsing with deionised water and then the $KMnO_4$ solution. The solution is run through the burette until it is below the 0 mL mark and there are no air bubbles in the tip. The oxalic acid solution is pipetted into conical flasks using a 25.0 mL pipette that have been rinsed with oxalic acid solution. The conical flasks will have been rinsed with deionised water. The oxalic acid solution is acidified with approximately 20 mL of H_2SO_4 solution (using the measuring cylinder) to encourage the formation of the appropriate products, and heated to increase the reaction rate. A minimum of four titrations should be conducted: a rough run, and three accurate runs with small differences between the volumes. The end point (and equivalence point) of the titration occurs when the solution in the conical flask turns and remains slightly pink. The titration does not need an indicator as the colour change of the $KMnO_4$ solution acts as an indicator (self-indicator). The reaction can be represented by the following equation:
   $$2MnO_4^-(aq) + 6H^+(aq) + 5C_2H_2O_4(aq) \; ! \;\; 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(!)$$

3.   The steel sample (a mass of between 0.5 and 1 g would be the most appropriate as this would give titration volumes for the $KMnO_4$ solution of around 25 mL) must be accurately weighed and dissolved in excess 2 mol L^{-1} H_2SO_4 solution. (It may need to be heated to aid the dissolving process). The solution should be filtered to remove solid impurities. The residue should be washed to ensure complete transfer of the iron in solution. The solution is then transferred to a volumetric flask (a 250 mL volume would be sufficient) and made up to the mark.

4.   The steel solution is then titrated with the $KMnO_4$ solution. The steel solution is pipetted into conical flasks and titrated. Again, there is no need for an indicator as the $KMnO_4$ takes on that role by changing colour as it reacts. *If the titration process was described fully in step 2 there is no*

need to repeat this information in detail. The reaction can be represented by the following equation:

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$$
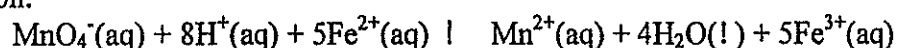
5. The percentage of iron in the steel can then be calculated from the data obtained. From the average titration volume, the concentration of the iron in the steel solution can be determined. From the total volume of the steel solution and the mass of the steel dissolved in step 3, the percentage of the iron in the steel can be determined.

A discussion of possible sources of error and how they could be minimised must be included. This could be done as part of the procedure or in a separate section.
Examples of the some of the sources of error are given below. This list is not exhaustive.

-   Rinsing equipment appropriately. Rinsing pipettes and burettes with deionised water will dilute the solutions slightly by an unknown amount and change the number of moles. Similarly, rinsing the conical flasks with solution will add an unknown number of moles of reactant.
-   Removing the funnel from the burette. A funnel can hold several drops of KMnO$_4$ solution that can add to the volume in the burette.
-   Correct use of a pipette, for example, allowing the tip of the pipette to rest for a sufficient time on the inside of the conical flask to allow complete transfer of solution.
-   Running solution through the burette to make sure there is no air bubble in the tip. This air bubble could disappear during a titration altering the total volume of the titration.
-   Reading the burette volume from the bottom of the meniscus and having the same person read the volume each time. This should give a more consistent reading.

The question also required that the equipment and chemicals used should be drawn from those given in the photographs.

Of the equipment and chemicals provided the following should not or need not be used
     FeSO$_4$(s)
     Anhydrous Na$_2$CO$_3$
     FeSO$_4$(aq)
     KMnO$_4$(s)   This could have been used but was not necessary
     Phenolphthalein indicator
     50 mL pipette