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Chemistry

2003 TEE Solutions*

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*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.

 acknowledges the support of the Curriculum Council and in particular the TEE Examining Panel members, Mrs Maree Baddock, Dr Stuart Bailey, Dr Steve Errington.

2003 CHEMISTRY TEE SOLUTIONS

PART 1 (60 MARKS)

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

PARTS 2 AND 3. For these parts the answers have been prepared along the following guidelines:

- These are a set of model answers. As such, there has been no attempt to cover all possibilities and thus clutter the document with qualifications. The aim has been to produce one set of answers that a good student could aspire to.
- In most cases only one answer has been given even when a number of other answers are correct.
- Occasionally in these model answers multiple solutions have been provided, as in Part 2 Q1, Q4 and Q9.

PART 2 (70 MARKS)

1. (a) $2\ H^+(aq)\ +\ Mg(s) \rightarrow H_2(g)\ +\ Mg^{2+}(aq)$

grey/silvery/white metal/solid dissolves [in colourless solution] to give colourless solution and colourless, odourless gas evolved

(b) $3\ Ba^{2+}(aq)\ +\ 2\ PO_4^{3-}(aq) \rightarrow Ba_3(PO_4)_2(s)$

2 colourless solutions react to form a white precipitate.

The following would also be acceptable
$3\ Ba^{2+}(aq)\ +\ 2\ H_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s)\ +\ 6\ H^+(aq)$
$3\ Ba^{2+}(aq)\ +\ 2\ H_2PO_4^-(aq) \rightarrow Ba_3(PO_4)_2(s)\ +\ 4\ H^+(aq)$
$3\ Ba^{2+}(aq)\ +\ 2\ HPO_4^{2-}(aq) \rightarrow Ba_3(PO_4)_2(s)\ +\ 2\ H^+(aq)$

(c) $Ag^+(aq)\ +\ 2\ NH_3(aq) \rightarrow Ag(NH_3)_2^+(aq)$

2 colourless solutions react to form a colourless solution **or** no change observed]

The following combinations would also be acceptable
$Ag^+(aq)\ +\ NH_3(aq)\ +\ H_2O \rightarrow AgOH(s)\ +\ (NH_4)^+(aq)$

or $2\ Ag^+(aq)\ +\ 2\ NH_3(aq)\ +\ H_2O \rightarrow Ag_2O(s)\ +\ 2\ (NH_4)^+(aq)$

and

$AgOH(s)\ +\ NH_4^+(aq)\ +\ NH_3(aq) \rightarrow Ag(NH_3)_2^+(aq)\ +\ H_2O$

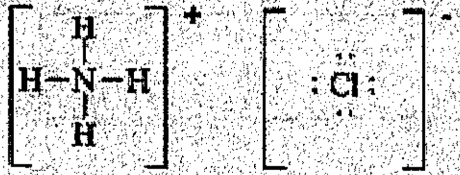
or $Ag_2O(s)\ +\ 2\ NH_4^+\ +\ 2\ NH_3(aq) \rightarrow 2\ Ag(NH_3)_2^+(aq)\ +\ H_2O$

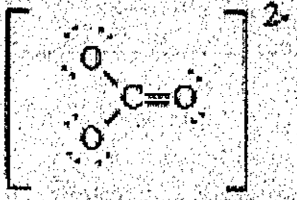
One colourless solution is added to another. At first a white/discoloured white/cream/grey/brown precipitate forms, but upon addition of further solution, a colourless solution results.

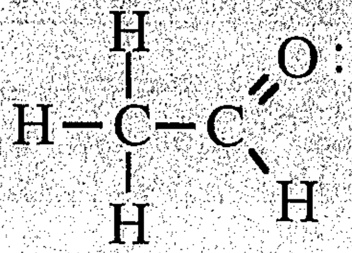
(d) No reaction or NR or no visible reaction or NVR.

[Colourless] liquid is added to an orange solution which remains orange **or** no change observed **or** no visible reaction **or** NVR.

2.







Or any equivalent positioning of double / single bonds

3. (a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ or [Ar]
(b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$ or $[Ar]\ 4s^1$

4.

Any salt of Fe^{2+}, Ni^{2+}, Cr^{3+}, also $CuCO_3$, $CuCl_2$
Al_2O_3, ZnO, Cr_2O_3
cyclohexene,
$Cu(NH_3)_4^{2+}$, $Zn(OH)_4^{2-}(aq)$
Phenolphthalein
Any metal, graphite, molten salts, ionic solutions
Diamond, graphite, silicon dioxide, Si, B,
Fe_2O_3, iron ore, iron oxide, coke, C(s), limestone, $CaCO_3$, air, oxygen, carbon monoxide, CO_2

5.

1,1,1-trichloroethane
ethyl acetate **or** ethyl ethanoate
2,2,4-trimethylpentane
1-propylcyclohexene

6.

YES
NO
NO
YES
NO

7.

NaC*l* (*l*)
anode: $2\,Cl^-(l) \rightarrow Cl_2(g) + 2\,e^-$
cathode: $Na^+(l) + e^- \rightarrow Na(l)$

NaC*l* (aq)
anode: $2\,H_2O(l) \rightarrow O_2(g) + 4\,e^- + 4\,H^+(aq)$
cathode: $2\,H_2O(l) + 2\,e^- \rightarrow H_2(g) + 2\,OH^-(aq)$

8. HC*l* is a strong acid which is fully ionised in aqueous solution, so $[H^+(aq)] = [HCl]$
$[\,HCl + H_2O \rightarrow H_3O^+(aq) + Cl^-(aq)\,]$
and $pH = -\log[H^+(aq)] = -\log 1.0 \times 10^{-3} = 3$

CH_3COOH is a weak acid, so only a small percentage is dissociated
$CH_3COOH + H_2O \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$
$[H^+(aq)] << [CH_3COOH] = 1.0$ so the pH could be around 3.

9. $Al(OH)_4^-(aq)$ **or** $Zn(OH)_4^{2-}(aq)$

$Al(OH)_4^-(aq) + H^+(aq) \rightarrow Al(OH)_3(s) + H_2O$

$Al(OH)_3(s) + 3\,H^+(aq) \rightarrow Al^{3+}(aq) + 3\,H_2O$

$Zn(OH)_4^{2-}(aq) + 2\,H^+(aq) \rightarrow Zn(OH)_2(s) + 2\,H_2O$

$Zn(OH)_2(s) + 2\,H^+(aq) \rightarrow Zn^{2+}(aq) + 2\,H_2O$

10. $4\,Au(s) + 8\,CN^-(aq) + O_2(g) + 2\,H_2O \rightleftharpoons 4\,Au(CN)_2^-(aq) + 4\,OH^-(aq)$

higher reactant concentration: $[CN^-(aq)]$ - not used as expensive and dangerous
higher reactant concentration (pressure of gas): PO_2 - pure oxygen is sometimes used rather than air, but not always, because of cost
remove $Au(CN)_2^-(aq)$ product by adsorption onto activated carbon, always used
remove $OH^-(aq)$ product by addition of acid – not used as this would react with cyanide, decreasing $[CN^-(aq)]$ and also producing poisonous HCN(g)

11. gold is a good electrical conductor
gold is noble, so does not corrode easily, and does not an have insulating corrosion product coating gold is malleable and ductile, so can readily be fabricated into fine shapes.

12. Numerous schemes are possible. An example:

Test	Substance identified	Explanation / Equation
solubility in water	Al_2O_3	This is insoluble, the other three are soluble
dissolve a little of each in water and add solution of $CaCl_2$	Na_3PO_4	This forms a (white) precipitate ($Ca_3(PO_4)_2$) $3\ Ca^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Ca_3(PO_4)_2(s)$
dissolve a little of each in water and add solution of $AgNO_3$	NaCl	This forms a (white) precipitate (AgCl) $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl\,(s)$
remaining substance	sugar	no precipitate

PART 3 (50 MARKS)

1(a) $Ni(s) + 4\ CO(g) \rightarrow Ni(CO)_4(g)$

(b) $n(CO) = \dfrac{2.76 \times 10^3}{22.41} \times \dfrac{273}{323} \times \dfrac{103.6}{101.3} = 106.4$ moles

$n(Ni) = \dfrac{1}{4} \times n(CO) = \dfrac{1}{4} \times 106.4 = 26.61$ moles

$m(Ni) = 26.61 \times 58.69 = 1562$ g

$m(\text{crude Ni}) = \dfrac{100}{80} \times 1562 = 1952$ g

2(a)

$n(C) = n(CO_2) = \dfrac{1.900}{12.01 + 2 \times 16} = 0.04317$ $\quad m(C) = 0.5185 \times 12.1 = 0.5185$ g

$n(H) = 2\ n(H_2O) = 2 \times \dfrac{0.518}{2 \times 1.008 + 16} = 0.05750$ $\quad m(H) = 0.05750 \times 1.008 = 0.05796$ g

$m(O) = 1.383 - \{m(C) + m(H)\} = 1.383 - (0.5185 + 0.05796) = 0.8065$ g $\quad n(O) = \dfrac{0.8065}{16.00}$
$= 0.05041$ mol

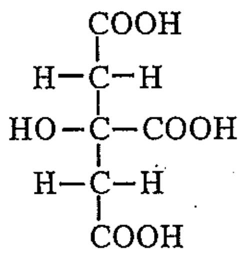
	C	H	O
mass (g)	0.5185	0.05796	1.383 – (0.5185 + 0.05796) = 0.8065
÷ At Wt	12.01	1.008	16.00
= (mol)	0.04317	0.05750	0.05041
÷ smallest no (0.04317)	1	1.332	1.1676
x 6	6	7.992	7.0056
Round	6	8	7

(b)

$EF = C_6H_8O_7 = (6 \times 12.01) + (8 \times 1.008) + 7 \times 16) = 192.1\ g\ mol^{-1}$ $\quad \frac{EF}{MF} = \frac{192.1}{192.1} = 1.000$

So $MF = EF = C_6H_8O_7$

(c)

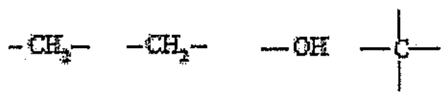


Or any other structure with 3 carboxylic acid groups and one OH group

Compound reacts with 3 moles KOH, so contains 3 acid groups

—COOH —COOH —COOH

Then there remains 3 more C, 5 more H, one O – these can be put together as



3(a)

$$\text{actual } n(Cu) = \frac{1.074}{63.55} = 1.690 \times 10^{-2} \text{ mol}$$

$$\text{this would require } \frac{8}{3} \times 1.690 \times 10^{-2} = 4.507 \times 10^{-2} \text{ mol } HNO_3$$

$$\text{actual } n(HNO_3) = 6.00 \times 10.0 \times 10^{-3} = 6.00 \times 10^{-2} \text{ mol } HNO_3$$

$$\text{this would require } \frac{3}{8} \times 6.00 \times 10^{-2} = 2.250 \times 10^{-2} \text{ mol Cu}$$

Hence Cu is limiting reagent, as there is sufficient nitric acid to react with all the copper, but insufficient copper to react with all the nitric acid. HNO_3 is thus in excess.

$$n(NO) = \frac{2}{3} \times n(Cu) = \frac{2}{3} \times 1.690 \times 10^{-2} = 1.127 \times 10^{-2} \text{ mol NO}$$

$$V(NO) = 1.127 \times 10^{-2} \times 22.41 \times \frac{101.3}{120.0} \times \frac{308}{273} = 0.2405 \text{ L NO}$$

(b)

$n(HNO_3)$ remaining = initial $n(HNO_3)$ - $n(HNO_3)$ reacting
= 6.00×10^{-2} mol - 4.507×10^{-2} mol
= 1.493×10^{-2} mol HNO_3

4(a) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

(b) $$n(Cu) = \frac{110.0}{63.55} = 1.731 \text{ mol}$$

$$n(e^-) = 2 \times n(Cu) = 2 \times 1.731 = 3.462 \text{ mol}$$

$$Q = n(e^-) \times F = 3.462 \times 9.649 \times 10^4 = 3.340 \times 10^5 \text{ C}$$

$$I = \frac{Q}{t} = \frac{3.340 \times 10^5}{3.05 \times 60 \times 60} = 30.4 \text{ A}$$

(c) $$n(Ni) = \frac{102.0}{58.69} = 1.738 \text{ mol}$$

$$\frac{n(Ni)}{n(e^-)} = \frac{3.462}{1.738} = 1.992$$

ie $Ni^{x+}(aq) + x e^- \rightarrow Ni(s)$

$x = 2$

(d) $n(Ni) = \frac{1.000 \times 10^6}{58.69} = 1.704 \times 10^4$ mol

$n(e^-) = 2 \times n(Ni) = 2 \times 1.704 \times 10^4 = 3.408 \times 10^4$ mol

$Q = n(e^-) \times F = 3.408 \times 10^4 \times 9.649 \times 10^4 = 3.288 \times 10^9$ C

$t = \frac{Q}{I} = \frac{3.288 \times 10^9}{10000} = 3.288 \times 10^5$ s $= 91.3$ hours

5(a) $6\, Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14\, H^+(aq) \rightarrow 6\, Fe^{3+}(aq) + 2\, Cr^{3+}(aq) + 7\, H_2O$

(b)

	1	2	3	4
Final volume	17.56	33.50	18.53	34.43
Initial volume	0.50	17.56	2.55	18.53
Titre	**17.06**	**15.94**	**15.98**	**15.90**

(c)

Excluding first (rough) value, average titre = $\frac{15.94 + 15.98 + 15.90}{3} = 15.94$ mL

$n(Fe^{2+}) = 0.04104 \times 15.94 \times 10^{-3} = 6.542 \times 10^{-4}$ mol

hence remaining $n(Cr_2O_7^{2-})$ in 30 mL aliquot = $n(Fe^{2+}) \times \frac{1}{6} = 6.542 \times 10^{-4} \times \frac{1}{6}$

$= 1.090 \times 10^{-4}$ mol

hence remaining $n(Cr_2O_7^{2-})$ in 150 mL = $n(Cr_2O_7^{2-}) \times \frac{150}{30} = 5.452 \times 10^{-4}$ mol

hence $n(Cr_2O_7^{2-})$ consumed = initial $n(Cr_2O_7^{2-})$ - remaining $n(Cr_2O_7^{2-})$
$= 0.005961 \times 0.1000 - 5.452 \times 10^{-4}$
$= 5.095 \times 10^{-5}$ mol

hence $n(CH_3CH_2OH)$ in 5 mL aliquot = $n(Cr_2O_7^{2-}) \times \frac{3}{2} = 5.095 \times 10^{-5} \times \frac{3}{2}$
$= 7.643 \times 10^{-5}$ mol

$[CH_3CH_2OH] = \frac{\text{mol}}{\text{Litres}} = \frac{7.643 \times 10^{-5}}{5.00 \times 10^{-3}} = 1.529 \times 10^{-2}$ mol L^{-1}

$[CH_3CH_2OH] = 1.529 \times 10^{-2} \times \{(2 \times 12.01) + (6 \times 1.008) + 16\}$

$= 1.529 \times 10^{-2} \times 46.068 = 0.7042$ g L^{-1}

(d) CH_3CH_2OH in 100 mL = $0.100 \times 0.7042 = 0.070542$ g = 70.42 mg

this is over the legal limit of 50 mg per 100 mL.

PART 4

This section is designed to give you the chance to demonstrate what you know and how you apply that knowledge, rather than determine what you do not know. Consequently, there is no one model answer. Different students could write extended answers with very different approaches and each gain full marks.

Clear setting out and logical order are important, as is clear concise English expression. Ideally, you should include a brief introduction as well as conclusion. It is imperative that if you are given additional information to which you are required to refer, this must be done, and in more detail than one or two sentences.

In general, then, for full marks we are looking for two pages (of normal writing) of:

- good chemistry
- on the topic given
- written in reasonable English (without too much concern on spelling)
- with some reasoning shown (for example, an inter-relating of evidence and theory)
- with a beginning, middle and an end,
- either no errors, or errors which are trivial, or errors which are thought to be slips, and

include diagrams, graphs, equations, drawings, schematic outlines and so on. Use whatever is appropriate to help you get your message across.

EXTENDED ANSWER 1

The key steps [the ordering is not of vital importance, although logic sort of suggests an obvious order] in an answer to this question are:

(1) A primary standard base solution must be prepared from anhydrous sodium carbonate by accurately weighing (an approximately chosen mass), and dissolving in (deionised) water, making up to the mark in a volumetric flask. [A discussion of primary standards is useful, but not essential. Further drying of the sodium carbonate would be sensible, but not essential]. A sodium carbonate concentration of close to 0.05 M would be a sensible target.

(2) The 0.1 M HC*l* should be standardised using the standard sodium carbonate solution. [Details of procedure could be given.] Methyl orange is a suitable indicator (weak base / strong acid).

(3) The 0.1 M NaOH should be standardised using the now standardised HC*l* solution. [Details of procedure could be given.] Methyl orange or phenolphthalein are suitable indicators (strong base / strong acid).

(4) Aliquots of wine should be titrated with the now standardised NaOH solution. [Details of procedure could be given.] Phenolphthalein is a suitable indicator (strong base / weak acid).

Error minimisation can be incorporated into good technique (replicates, funnel out of burette, correct rinsing, appropriate indicators).

EXTENDED ANSWER 2

As mentioned in the rubric to extended answer 2, you must discuss a number of issues. These cover primary and secondary cells (which will draw in dry cells and the lead acid accumulator). The principles of operation of cells must also be addressed, along with a consideration of suitability of certain types of cells for various applications.

Different approaches may be taken to the structure of the answer. A thoughtful approach may involve:

(1) Definition of electrochemical cells. This may cover redox reactions - oxidation and reduction half reactions, and their combination, based on electron transfer. The anode and cathode, perhaps the cell potential could be defined and examples given. The spontaneous reaction produces energy [which is the useful product].

(2) Primary cells can only react in one direction (ie it cannot be reversed / recharged), so once the reactants are consumed, it is flat and spent and no more energy can be obtained.

(3) Examples of primary cells could be given, including the dry cell and those in the table. A comparison could be made here.

(4) Secondary cells could be defined here - when the battery is flat, the anode and cathode are reversed by the application of electrical energy to recharge the cell. [ie it operates as an electrolytic cell during recharge].

(5) Examples of secondary cells could be given, including the lead accumulator and those in the table. A comparison could be made here.

As the objective is to obtain energy, the more energy the better. This is related to the voltage, and also the number of coulombs available, so a high voltage is a favourable attribute. For portable applications, a low mass is also desirable, as is rechargeability. This must sometimes be balanced against the cost/environmental etc factors associated with the components. These matters related to the applications may be discussed separately, or integrated into the discussion of the cell types.

Discussion of or referral to the cells/batteries listed in the table is ESSENTIAL!