TEE Chemistry 1998 Solutions

Part 1

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

For Parts 2 and 3 the answers have been prepared according to the following guidelines.

* We have tried to prepare a set of model answers. As such we have not attempted 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 other answers are correct
* In the calculations, a method of working has been used which emphasises reasoning. The answers given here are modelled on approaches adopted by students where their schools have been conspicuously successful in public examinations.

Part 2

1 (a) $H^+(aq) + NaOH(s) \rightarrow Na^+(aq) + H_2O(l)$
White solid dissolves

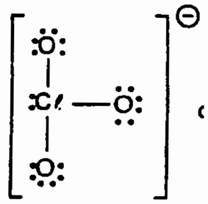
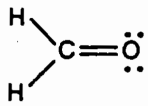
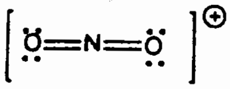
(b) $CH_3CH_2COOCH_2CH_3(aq) + OH^-(aq) \rightarrow CH_3CH_2CO_2^-(aq) + CH_3CH_2OH(aq)$
Sweet odour disappears

(c) No reaction, so no equation
No visible reaction

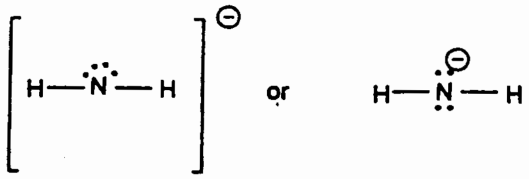
(d) $Hg_2^{2+}(aq) + 2Br^-(aq) \rightarrow Hg_2Br_2(s)$
Yellow (or white) precipitate forms (colour must be stated)

2. (a) $1s^2\ 2s^2\ 2p^6\ 3s^2$
(b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

3.

Species	Structural formula	Shape
Chlorate ion ClO_3^-		Pyramid
Methanal H_2CO		Triangular planar
Nitronium ion ONO^+		Linear

4. Amide ion



Equation:
$NaNH_2(s) + H_2O(l) \rightarrow Na^+(aq) + NH_3(g) + OH^-(aq)$

5. H_2O_2: the H_2O_2 has disproportionated

MnO_2: the MnO_2 acted as a catalyst - no change

Gas produced: oxygen

6. i) White precipitate: AgCl
ii) Yellow precipitate: AgI
iii) $AgCl(s) + 2NH_3(aq) \rightarrow Ag(NH_3)_2^+(aq) + Cl^-_{(aq)}$
iv) The white solid is more soluble than the yellow solid.

7.

Higher boiling point compound	**Intermolecular force responsible for the difference**
Cl_2	Dispersion force
CH_3CH_2OH	Hydrogen bonding
$CH_3CH_2CH_2OH$	Dispersion force
ICl	Dipole-dipole bonding

8. Oxidation half equation

$TeO_2 + 2H_2O \rightarrow TeO_4^{2-} + 4H^+ + 2e^-$

Reduction half equation

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

Redox equation

$Cr_2O_7^{2-} + 3TeO_2 + 2H^+ \rightarrow 3TeO_4^{2-} + 2Cr^{3+} + H_2O$

9. a) No: Only SO_4^{2-} and Ba^{2+} ions are involved

b) $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

c) PO_4^{3-} reacts with H^+ **or** PO_4^{3-} is a stronger base than SO_4^{2-} **or** H_3PO_4 is a weaker acid than H_2SO_4

d) HCl

Adding H_2SO_4 would add more SO_4^{2-}

10. i)

What is done	**How the equilibrium shifts**
More gold added	no change
Pressure of oxygen is increased	$\rightarrow$
Temperature is increased	$\leftarrow$

ii) Function of the carbon:

To adsorb (or concentrate) the $Au(CN)_2^-$ ion

iii) Why not carried out in acid solution?

Chemical reason CN^- is lost or $[CN^-]$ is reduced
Practical reason HCN is formed or HCN is dangerous/poisonous

11. i)

NH_3	+	H_2O	$\rightarrow$	NH_4^+	+	OH^-
$CH_3(CH_2)_{16}CO_2^-$	+	H_2O	$\rightarrow$	$CH_3(CH_2)_{16}COOH$	+	OH^-

ii)

The octadecanoate ion has a polar end and a non-polar end.
The non-polar end mixes with the grease and the charged end mixes with the water

iii)

Ammonia appropriate: left over ammonia can evaporate.
Or
Sodium octadecanoate not appropriate: it remains on the floor and may be slippery

iv)

Why is ammonia not appropriate in a bath:
Ammonia has a pungent odour **or** may burn/irritate eyes or skin

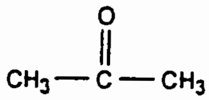
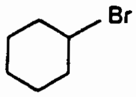
12.

Solute	**pH of solution**
NH_4Cl	Acidic
Na_2CO_3	Basic
NaCl	Neutral
KCH_3CO_2	Basic

13.

Compound	Class	Compound	Class
$(CH_3)_2CHCH(CH_3)_2$	Alkane	$CH_3CHBrCH_3$	Haloalkane or alkyl halide
$CH_3CH(OH)CH_3$	Secondary alcohol	$CH_3COCH_2CH_3$	Ketone
$CH_3CH(NH_2)CH_3$	Amine	$CH_3CH_2OOCCH_3$	Ester
$HCOCH_3$	Aldehyde	$HCOOCH_3$	Ester

14.

(a)	$CH_3CH_2CH_2O^-$ or $CH_3CH_2CH_2O^-Na^+$
(b)	CH_3COCH_3 or 
(c)	 Note: $C_6H_{11}Br$ not acceptable
(d)	$CH_3CH_2CH_2COO^-$ or $CH_3CH_2CH_2COO^-Na^+$

PART 3

1. $CuSO_4.5H_2O$ + $BaCl_2.2H_2O$ → $BaSO_4$

a) $n(CuSO_4.5H_2O) = 2.136 \div 249.69 = 8.5546 \times 10^{-3}$ mol

$\therefore n(BaCl_2.2H_2O) = 8.5546 \times 10^{-3}$ mol

$\therefore m(BaCl_2.2H_2O) = 8.5546 \times 10^{-3} \times 244.23$

$= 2.089$g (4sf)

b) $n(BaSO_4) = n(BaCl_2.2H_2O) = 8.5546 \times 10^{-3}$ mol

$\therefore m(BaSO_4) = 8.5546 \times 10^{-3} \times 233.36$

$= 1.996$g (4sf)

c) Theoretical yield:

$n(CuCl_2.2H_2O) = n(CuSO_4.5H_2O) = 8.5546 \times 10^{-3}$ mol

$\therefore m(CuCl_2.2H_2O) = 8.5546 \times 10^{-3} \times 170.482$

$= 1.458$ g (in theory)

Actual yield = 0.785g

$\therefore$ % yield $= (0.785 \div 1.458) \times 100$

$= 53.8\%$ (3sf)

d) Some water of crystallisation may be lost or the product may be impure.

e) No, it is not necessary to weigh the sodium carbonate accurately as long as the sodium carbonate is in excess, so that all the Cu^{2+} is precipitated as $CuCO_3$.

2. (a) $Ag_2O + 2e^- + H_2O \Leftrightarrow 2Ag + 2OH^-$ + 0.34 V
$Zn + 4OH^- \Leftrightarrow Zn(OH)_4^{2-} + 2e^-$ + 1.20 V
$\therefore$ voltage of cell = + 1.34 V

(b) Q = It = $0.0150 \times 10^{-3} \times 400 \times 24 \times 60 \times 60$
= 518.4
n(e-) = $518.4 \div 9.649 \times 10^4$
= 5.373×10^{-3} mol

(c) $Ag_2O + 2e^- \Leftrightarrow 2Ag + 2OH^-$
$n(Ag_2O)$ = ½ n(e-)
$\therefore m(Ag_2O)$ = $½ \times 5.373 \times 10^{-3} \times 231.8 \times 100/85$
= 0.733 g

(d) m(Ag) = $0.7326 \times (215.8/231.8)$
= 0.6820 g
cost Ag = 0.6820×35.3
= 24.1 cents

(e) The conditions were not standard.
The concentrations were not 1.00 mol L^{-1}.

3. (a) (i) 0.5 mol of iodine
(ii) 2.0 mol of thiosulfate ion
(iii) 1.0 mol of thiosulfate ion

(b)

Final reading	17	16.5	15.68	15.12	16.28
Initial reading	0.22	1.10	0.66	0.06	1.24
Titration volume	**16.78**	**15.40**	**15.02**	**15.06**	**15.04**

Ignore readings 1 & 2 (not consistent)
So titration volume = (15.02 + 15.06 + 15.04)/3
= 15.04 mL

(c) $2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$

$n(S_2O_3^{2-})$ = $15.04 \times 10^{-3} \times 0.051103$ = 7.675×10^{-4}
$n(Cu^{2+})$ in 25 mL = $n(S_2O_3^{2-})$ = 7.675×10^{-4}

$n(Cu^{2+})$ in 250 mL= $7.675 \times 10^{-4} \times 250/25$ = 7.675×10^{-3}
$m(Cu)$ = $7.675 \times 10^{-3} \times 63.54$ = 0.4877 g
% Cu = $(0.4877/6.056) \times 100$
= 8.053%

4. (a) $n(H+)$ = $50.00 \times 10^{-3} \times 0.0197$
= 9.85×10^{-4} mol
(b) $n(OH^-)$ = $5.62 \times 10^{-3} \times 0.100$ = 5.62×10^{-4} mol
∴ $n(H^+)$ = 5.62×10^{-4} mol

(c) n(HCl) reacting with NH_3 = $9.85 \times 10^{-4} - 5.62 \times 10^{-4}$
∴ $n(NH_3)$ = $9.85 \times 10^{-4} - 5.62 \times 10^{-4}$ mol
∴ $n(N)$ = $9.85 \times 10^{-4} - 5.62 \times 10^{-4}$ = 4.23×10^{-4} mol
∴ $m(N)$ = $4.23 \times 10^{-4} \times 14.01$ = 5.926×10^{-3} g
% N = $(5.926 \times 10^{-3} \div 1.254) \times 100$
= 0.473%
(d) Nitrogen is not lost because the acid keeps the N in as the NH_4^+ ion **or** the nitrogen is combined in a compound.

5. $Cu_x(CO_3)_y(OH)_z$ ⟶ CuO + CO_2 + H_2O
2.0881 g 1.444 g 0.531 g 0.109 g

$m(Cu)$ = $1.444 \times 63.54 \div 79.54$ = 1.1535 g
$m(CO_3)$ = $0.531 \times 60.01 \div 44.01$ = 0.72405 g
$m(OH)$ = $0.109 \times 17.008 \div 18.016$ = 0.2058 g

	Cu	CO_3	OH
mass	1.1535 g	0.72405 g	0.2058 g
Formula mass	63.54	60.01	17.008
n=m/M	0.01815	0.01207	0.01210
ratio	1.505	1.00	1.003
whole no ratio	3.009	2.00	2.006
Rounding	3	2	2

so empirical formula = $Cu_3(CO_3)_2(OH)_2$

b) Species are: Cu^{2+}, CO_3^{2-}, OH^-
This is consistent since the sum of the charges is zero:
3 × 2+ = +6
2 × 2- = -4
2 × 1- = -2
Total = 0

PART 4

This section is designed to give you the opportunity to demonstrate what you know rather than what you do not know. Hence there is no one model answer. Several students could write quite different essays and yet all could score full marks.

Clear setting out and logical order are important, as is clear and concise English expression. Ideally you should include a brief introduction and conclusion.

In general, for full marks you need to write 2 pages of:
* good chemistry
* on the topic given
* written in reasonable English
* with reasoning, relating evidence and theory - reasoning and argument are important
* with a beginning, middle, and an end

Diagrams, graphs and drawings should be included if this is an appropriate method for getting your message across.

Q1
The following points could be made:
- Relate the elements to their position in the periodic table
  K is a metal, Cr is a transition metal,
  Ge is a metalloid, Br_2 is a non-metal.
  Describe the types of bonding: metallic, covalent network, covalent molecular - nature, relative strengths
  Identify K and Cr as metallic, Ge as network covalent, Br existing as Br_2 molecules linked by weak dispersion forces.
- In K and Cr, melting requires the disruption of relatively strong metallic bonds. The MP increases as the number of electrons in metal-metal bonding increases.
  In Ge melting requires breaking of the very strong network covalent bonds, hence considerable energy is needed (high MP).
  In Br_2, only weak intermolecular van der Waals forces need to be broken, hence the low MP
- First ionisation energy depends on the strength of attraction between the electron cloud and the nucleus. This increases from left to right in the periodic table, as the charge on the nucleus increases (similar radius, but increasing nuclear charge).
- Electrical conductivity depends on how easily it is for electrons to be displaced.
  K and Cr are metals with delocalised valence electrons which are easily displaced.

In Ge the electrons are held by strong covalent bonds, so its conductivity is low (but being a metalloid it has some metallic properties with some delocalisation of electrons).
In Br_2, electrons are held by strong covalent bonds so it has a very low electrical conductivity (conductivity is further impeded by the lack of a continuous structure).

- Melting point depends on the strength of the bonds.
  KCl and $CrCl_3$ are ionic compounds, and melting requires considerable energy to disrupt the strong ionic bonds in the crystal lattice.
  $GeCl_4$ and BrCl are covalent molecular molecules, and melting only requires the breaking of the relatively weak inter-molecular (van der Waals) forces.

* Reasoning must be shown (a 2 page statement of factual examples with no reasoning is worth a maximum of 10/20).

Q2
This essay asks you to compare and contrast.
The following points could be made:

	Electrochemical cell	Electrolytic cell
Half cells	Two half cells are separated	
Electrons	Flow spontaneously from the half cell with the more negative potential	Reaction does not take place spontaneously - external energy source needed
Electrons	Spontaneously flow from anode to the cathode	Forced to flow to the cathode
Anode	Site of oxidation negative	Site of oxidation positive
Cathode	Site of reduction The positive terminal	Site of reduction The negative terminal
	Stored chemical energy is converted into electrical energy	Electricity used to cause a chemical reaction
Net E^0	Positive	Negative
Possible examples	Dry cell Lead acid accumulator	Electro-refining of gold Electro-refining of aluminium Electro-refining of copper Electroplating Anodising Electrolysis of molten and aqueous NaCl

Q3
This is the open-ended essay of this exam, and there are a wide variety of approaches that could be used.

Possible discussion points include:

- Define isomerism
- Explain some of the types of isomerism - for example students may select one or more of these
  - chain
  - geometric eg cis-trans
  - position
  - structural
- Illustrate discussion with examples
- Explain how the chemical properties of isomers vary eg as in 1, 2 and tertiary butanol
- Explain how the physical properties of isomers vary Eg MP and BP of: geometric - cis and trans-2-butene
  chain - butane and methylpropane