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Chemistry

2001 TEE Solutions*

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The Curriculum Council
27 Walters Drive
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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.

 STAWA appreciates the support of the Curriculum Council, which provided the marker's guides used a basis for these solutions.

TEE Chemistry 2001 Solutions

Part 1

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

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

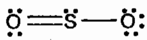
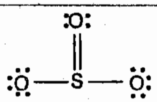
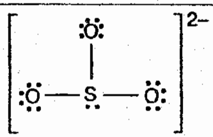
1. (a) $Cu^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CuCO_{3(s)}$
   [Blue] solution gives blue (or blue-green) precipitate.

   (b) $Na_2SO_{3(s)} + 2H^+_{(aq)} \rightarrow SO_{2(g)} + H_2O_{(l)} + 2Na^+_{(aq)}$
   White solid dissolves, pungent, colourless gas evolved.

   (c) No reaction
   No visible reaction

   (d) $CH_3COOH + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3 + H_2O$
   Pungent odour produced (fruity/sweet smelling odour also accepted).

2.

Species	Structural Formula	Shape	Polarity
Sulfur dioxide SO_2		bent	Polar
Sulfur trioxide SO_3		Triangular planar	Non-polar
Sulfite ion SO_3^{2-}		pyramidal	polar

3. Please note for this question that there are multiple answers for each part.

(a) C_6H_6, graphite

(b) NaCl

(c) 1,1-diaminopropane

(d) NH_4NO_3

(e) manganese

(f) ethene

(g) carboxylic acid

4. (a) $Na_2CO_3 + 2H^+ \rightarrow 2Na^+ + CO_2 + H_2O$

(b) Pass the gas through limewater

(c) A white precipitate is formed.
$Ca^{2+} + 2OH^- + CO_2 \rightarrow CaCO_3 + H_2O$

5. (a) The HPO_4^{2-} is a weak base, which will react with, water as follows:
$HPO_4^{2-} + H_2O \rightarrow H_2PO_4^- + OH^-$
The Na^+ does not react in a similar way with water, so the presence of excess hydroxide ions makes the solution basic.

(b) The following reactions of the ions occur with water
$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$
$CH_3COO^- + H_2O \rightarrow CH_3COOH + OH^-$
Since both reactions occur to approximately the same extent there is not an excess of hydroxide or hydronium ions and hence the solution is neutral.

6.

Experiment and Observation	Explanation
A little concentrated hydrochloric acid is added and the mixture turns more blue and less red	Added Cl^- ions drive the equilibrium position to the right.
A little silver nitrate solution is added. There is a precipitate and the mixture turns more red and less blue.	Added Ag^+ ions will precipitate Cl^- as AgCl. The removal of the Cl^- ions will drive the equilibrium position to the left.
The solution is warmed and the mixture turns more blue and less red.	The reaction must be endothermic. As the solution is warmed the equilibrium position will be driven to the right.

7. (a) $$K = \frac{[Au(CN)_2^-]^4[OH^-]^4}{[O_2][CN^-]^8}$$

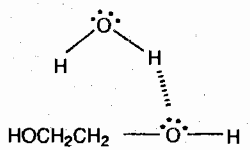
(b) $$K = \frac{[HI]^2}{[H_2][I_2]}$$

8. (a) $2Rb + 2H_2O \rightarrow 2Rb^+ + 2OH^- + H_2$

(b) Rapid. Rb is in the same group as Na, which reacts rapidly with water.

9. (a) Primary

(b) Hydrogen bonding occurs between the molecules of 1,2-diethanediol and water. This enables the intermolecular bonding in the mixed state to compete effectively with the intermolecular bonding within the separate components.



10. (a) A or E

D or B

(b) $2CH_3CH_2CH_2CH_2CH_2OH + 2Na \rightarrow 2\ CH_3CH_2CH_2CH_2CH_2O^- + H_2 + 2\ Na^+$

(c)

slowest reaction	intermediate rate of reaction	fastest reaction
C	B and D	A and E

Part 3

1 (a) 0.4 mol

$$n(MnO_4^-) = \frac{26.40}{1000}(0.03004) = 7.390x10^{-4}$$

$$n(V)_{in50mL} = 7.390x10^{-4}(\frac{5}{2}) = 1.847x10^{-3}$$

(b)

$$n(V)_{in250mL} = 1.847x10^{-3}(\frac{250}{50}) = 9.237x10^{-3}$$

$$m(V)_{in250mL} = 9.237x10^{-3}(50.94) = 0.4705$$

$$\%(V) = \frac{0.4704}{0.8765}(100) = 53.68\%$$

2. (a) $K_2S_2O_5 + 2H^+ \rightarrow 2SO_2 + H_2O + 2K^+$

(b) m(12000L) = 12000(1000)

= 12000000 g

n (SO_2) required $= \frac{12000000(0.000045)}{64.06}$

= 8.430 mol

n($K_2S_2O_5$)required $= 8.430(\frac{1}{2})$

= 4.215 mol

m($K_2S_2O_5$) required = 4.215(222.32)

= **9.4 x 10^2 g**

(c) $SO_2 + H_2O_2 \rightarrow 2H^+ + SO_4^{2-}$

(d) $n(OH^-) = \frac{6.51}{1000}(0.0092)$
$= 5.989 \times 10^{-5}$
$=$ no of mol of H^+

$n(SO_2) = 5.989 \times 10^{-5}(\frac{1}{2})$
$= 2.995 \times 10^{-5}$

$m(SO_2) = 2.995 \times 10^{-5}(64.06)$
$= 1.919 \times 10^{-3}$ g

$m(SO_2)$ppm $= 1.919 \times 10^{-3}(\frac{1000000}{40})$
$=$ **48.0 ppm**

(a) $Fe_wC_xH_yO_z \rightarrow Fe_2O_3 + CO_2 + H_2O$

1.3270 g → 0.392 g + 3.037 g + 0.615 g

$m(C) = 3.037(\frac{12.01}{44.01})$
$= 0.8288$ g

$m(H) = 0.615(\frac{2(1.008)}{18.016})$
$= 0.06882$ g

$m(Fe) = 0.392(\frac{2(55.87)}{159.7})$
$= 0.2742$ g

	Fe	C	H	O
Mass(g)	0.2742	0.8288	0.06882	1.3270 – (0.2742 +0.8288+0.06882) =0.1552
÷ At Wt	55.85	12.01	1.008	16.00
=(mol)	0.004909	0.06901	0.06827	0.009699
÷Smallest number (0.004909)	1	14.06	13.91	1.98
Round	1	14	14	2

So empirical formula is **$FeC_{14}H_{14}O_2$**

(b) The gas at 303 K and 98 kPa occupies 71 mL, so at 298 K and 101.3 kPa the gas volume will be

$$V = 71(\frac{298}{303})(\frac{98}{101.3})$$
$$= 67.55 \text{ mL}$$
$$n(gas) = \frac{0.06755}{24.47}$$
$$= 0.002761 \text{ mol}$$

$$n(X) = \frac{1}{2} n(gas)$$
$$= 0.001380 \text{ mol}$$

$$M(X) = \frac{0.375}{0.001380}$$
$$= \mathbf{272}$$

(c) MWt of $FeC_{14}H_{14}O_2$ = 270.2 ≈272
∴ molecular formula = empirical formula = $\mathbf{FeC_{14}H_{14}O_2}$

4. (a) $n(I_2O_5) = \frac{32.07}{333.8}$
$= 0.09608$ mol

$n(SF_4) = \frac{120(6.02)}{8.315(349)}$
$= 0.2489$ mol

0.2489 mol of SF_4 would require $0.2486(\frac{2}{5}) = 0.09957$ mol of I_2O_5 which is not available (0.09608 < 0.09957). Therefore I_2O_5 is the limiting reactant.

$$n(SO_2) = 0.09608(\frac{5}{2})$$
$$= 0.2402 \text{ mol}$$
$$V(SO2) = \frac{0.2402(8.315)(349)}{120}$$
$$= \mathbf{5.81\ L}$$

(b)

	Number of mole	Molecular Weight (g mol^{-1})	Mass (g)
I_2O_5	0		0
SF_4	0.2489-(5/2 x 0.09608) =0.008700	108.06	0.940
IF_5	0.09608 x 4/2 = 0.1922	221.9	42.6
SO_2	0.09608 x 5/2 = 0.2402	64.06	15.4

5. (a)

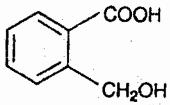
$$n(CH_4) = \frac{1.0(0.043)}{0.08206(298)}$$
$$= 0.001758 \text{ mol}$$

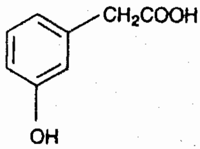
$$n(C_8H_8O_3) = \frac{0.1345}{152.144}$$
$$= 0.0008840$$

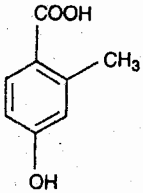
$$n(\text{active H atoms}) = \frac{0.001758}{0.0008840}$$
$$= 1.99 \approx 2$$

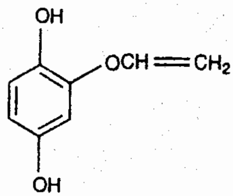
∴ 2 active H atoms

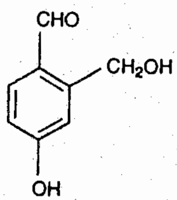
(b) There are a number of structures that could be correct, a small sample is included below.











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 at least 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 equations should be included if this is an appropriate method for getting your message across.

With the change in style of questions it is also crucial to relate the information given in the question to what you already know. A simple rewriting of the question is not an acceptable answer.

Question 1

This question could have been tackled from a number of directions, all equally valid. Some of the possible points that could have been made include:

- Pure H_2SO_4 is a liquid at room temperature while H_3PO_4 is a solid at room temperature. This could be related to intermolecular forces.
- H_3PO_4 is a weak triprotic acid while H_2SO_4 is a strong diprotic acid. Equations demonstrating that could be given here.
- Concentrated H_2SO_4 is dehydrating agent, so is concentrated H_3PO_4, although the anhydride (P_4O_{10}) is more powerful one.
- Both acids can be used in fertilizers, but H_2SO_4 is mainly used as an industrial acid.
- The production methods of H_3PO_4 and H_2SO_4 can be compared and contrasted.
- The reactions in both production methods are exothermic, although the reactions in the production of H_3PO_4 produce a much greater amount of energy per mole than in the production of H_2SO_4.
- A catalyst is required to aid in the conversion of SO_2 to SO_3, which is slow at room temperature. The conversion of P_4 to P_4O_{10} is spontaneous at room temperature and does not require a catalyst. This could be related to activation energy. (Activation energy diagrams could be drawn here)
- The changes in oxidation states of the phosphorus and the sulfur could be followed in each process.
- Equations should be provided for the steps in both production processes.

Question 2

The question required that the examples provided be used in the answer and that all examples be referred to with both solvents.

The following points were required as part of the essay:

- The intermolecular forces between hexane molecules are relatively weak dispersion forces.
- The intermolecular forces between water molecules include the much stronger hydrogen bonding forces.
- The mixing of two species involves a competition between the solute-solute intermolecular forces, the solvent-solvent intermolecular forces and the solute-solvent intermolecular forces.

The following points could have been made:

- Species tend to mix.
- Water and methanol both contain hydrogen bonds and can form hydrogen bonds with each other.
- While 1-pentanol contains hydrogen bonding, it's significant intermolecular forces are dispersion forces. The dispersion forces cannot compete effectively with the hydrogen bonding between the water molecules and so water and 1-pentanol are only partially miscible.
- Decane is non-polar and its molecules are linked by relatively weak dispersion forces. The only bonds that can form between decane and water are dispersion forces which are weaker than the decane-decane dispersion forces due the small size of the water molecule. The hydrogen bonding in water is too strong to be disrupted in such a situation to allow for the dissolving of decane.
- Methanol and, to a greater extent, 1-pentanol have stronger dispersion forces than water. The stronger dispersion forces provide methanol and 1-pentanol with the ability to dissolve in hexane.
- Decane and hexane both have relatively weak dispersion forces between their molecules. Similar strength bonds are formed between decane and hexane molecules, allowing mixing to occur.
- In ionic substances the forces holding the ions together vary in strength. Where the interactions between the ions and water molecules are large enough, the bonds within the ionic lattice will be broken. This occurs for NaCl. For silver chloride the bonds holding the ions together are stronger and the attraction of the ions for the water molecules are not strong enough to break the ionic bonds.
- In sugar there are a large number of OH groups which allow for hydrogen bonding to occur within the molecule. The dispersion forces within the molecule are relatively weak.