Neap

Trial Examination 2022

VCE Chemistry Unit 2

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

1	A	B	C	[✓ D]
2	[✓ A]	B	C	D
3	A	[✓ B]	C	D
4	A	B	C	[✓ D]
5	A	[✓ B]	C	D
6	A	B	[✓ C]	D
7	A	[✓ B]	C	D
8	[✓ A]	B	C	D
9	[✓ A]	B	C	D
10	A	[✓ B]	C	D

11	A	[✓ B]	C	D
12	A	B	C	[✓ D]
13	[✓ A]	B	C	D
14	A	B	[✓ C]	D
15	A	B	C	[✓ D]
16	A	B	[✓ C]	D
17	[✓ A]	B	C	D
18	A	B	[✓ C]	D
19	A	B	C	[✓ D]
20	A	B	[✓ C]	D

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Question 1 D

D is correct. HPO_4^{2-} can donate a proton to produce PO_4^{3-} or it can accept a proton to form $H_2PO_4^-$; therefore, HPO_4^{2-} is amphiprotic. It is also monoprotic because it can only donate one proton.

A, **B** and **C** are incorrect. These options do not correctly describe HPO_4^{2-}.

Question 2 A

A is correct. Iron ions are reduced ($Fe^{3+} + 3e^- \rightarrow Fe$) and act as the oxidant in the reaction.

B is incorrect. The oxidation reaction is $O^{2-} + CO \rightarrow CO_2 + 2e^-$. CO is oxidised and so is the reductant in the reaction.

C is incorrect. The oxidation number of carbon increases from +2 in CO to +4 in CO_2. This increase in oxidation number represents oxidation of carbon, not reduction.

D is incorrect. The oxidation number of oxygen throughout the reaction is –2, so no oxidation of oxygen atoms occurs.

Question 3 B

B is correct, and **A** and **C** are incorrect. At point K, the ice melts to form liquid water; at point L, the liquid water heats up; and at point M, the liquid water changes state to a vapour.

D is incorrect. There is only water vapour present at point N.

Question 4 D

D is correct. The heating curve for water involves the disruption of intermolecular hydrogen bonding, not covalent bonding within the water molecules.

A, **B** and **C** are incorrect. Covalent bonding requires much higher temperatures to be disrupted.

Question 5 B

B is correct. Organic acids, such as citric acid, are weak acids. With a concentration of 0.100 M, the acid solution is dilute.

A, **C** and **D** are incorrect. These options do not correctly describe the concentration of the solution and the strength of citric acid.

Question 6 C

In the neutralisation reaction between nitric acid (HNO_3) and sodium hydroxide (NaOH), the mole ratio of NaOH : HNO_3 is 1 : 1.

$n(\text{NaOH}) = n(\text{HNO}_3) = cV = 1.00 \times 30.0 \times 10^{-3}$ mol

In the neutralisation reaction between citric acid and NaOH, the mole ratio of NaOH : citric acid is 3 : 1.

$$n(\text{citric acid}) = \frac{1}{3} \times n(\text{NaOH}) = \frac{1}{3} \times 1.00 \times 30.0 \times 10^{-3} = 10.0 \times 10^{-3} \text{ mol}$$

$$V(\text{citric acid}) = \frac{n}{c} = \frac{10.0 \times 10^{-3}}{0.100} = 0.100 \text{ L} = 100 \text{ mL}$$

Question 7 B

As $c_1V_1 = c_2V_2$, $0.100 \times 0.150 = 0.0650 \times V_2$.

$V_2 = 0.2308$ L = 230.8 mL

volume of water that must be added = 230.8 – 150 = 81 mL

Question 8 A

A is correct. The specific heat capacity of water is high, not low. This is due to the relatively strong intermolecular bonding between water molecules, which must be disrupted to raise the kinetic energy of the molecules and so raise the temperature.

B, **C** and **D** are incorrect. These options are all properties of water.

Question 9 A

A is correct. A conjugate redox pair consists of a reductant and its oxidised form, such as Fe and Fe^{2+}.

B, **C** and **D** are incorrect. The two species in each of these pairs are not related to each other as oxidised and reduced forms in the given equation. For example, the oxidation numbers of H and O do not change from H_2O to OH^-, and O_2 and H_2O are both reactants in the equation.

Question 10 B

B is correct. A weak base only partially reacts with water. A hydroxide ion is formed when the water donates a proton to the base. The hydroxide ion is itself a base, so it can accept a proton.

A is incorrect. Upon reaction with water, a base will produce hydroxide ions, not hydronium ions.

C is incorrect. A pH greater than 12 and less than 14 indicates a strong base.

D is incorrect. A base accepts a proton or hydrogen ion, not a hydrogen atom.

Question 11 B

n(sodium carbonate, Na_2CO_3) = $cV = 0.156 \times 0.2500 = 0.0390$ mol

$m(Na_2CO_3) = n \times M = 0.0390 \times 106.0 = 4.13$ g

Question 12 D

D is correct. By definition, the end point is the point at which the indicator shows a permanent colour change.

A is incorrect. If the acid and base are of different concentrations, the volumes reacting will not be equal.

B is incorrect. This option describes the equivalence point.

C is incorrect. The pH in the reaction flask may be 7 for a strong acid with strong base titration but will be above or below 7 if weak acids or bases are involved in the titration. Weak acids and bases produce weak bases and acids, respectively, at the equivalence point, and so the pH may not be 7.

Question 13 A

A is correct. It is proper scientific procedure to take more than one sample so that an average result can be calculated. The average is more reliable than a single piece of data.

B is incorrect. The samples are not pooled, and the 20.00 mL samples are more than sufficient to conduct tests without the suggested pooling.

C is incorrect. This option could be a valid reason if basic competence was an issue, but it is not the main reason for taking multiple samples.

D is incorrect. Only one wavelength is selected to analyse the samples. The samples are not consumed in the process of reading absorbance, so even if readings were to be made at different wavelengths, extra samples would not be required for this purpose.

Question 14 C

C is correct. The wavelength is selected so that the permanganate ion, MnO_4^-, absorbs strongly, and other components of the mixture absorb minimally. This increases the accuracy of concentration determinations.

A is incorrect. MnO_4^- absorbs strongly at this wavelength.

B is incorrect. Water is unlikely to absorb much radiation at any wavelength, and the purpose of selecting a particular wavelength is to maximise absorption of the substance under analysis.

D is incorrect. One wavelength cannot be effective at absorbing all colours.

Question 15 D

From calibration curve, an absorbance of 0.35 corresponds to a concentration of 55 mg L^{-1}. As the original sample was diluted by a factor of 12.5 $\left(\frac{250.0}{20.00} = 12.5\right)$, then the undiluted concentration = 55 × 12.5 = 687.5 mg L^{-1} = 6.9×10^2 mg L^{-1}.

Question 16 C

C is correct. Only statements I and III are accurate.

A, **B** and **D** are incorrect. Statement II is incorrect; 2.5% of water on Earth is fresh water.

Question 17 A

A is correct. Carbon dioxide gas reacts with water to form carbonic acid according to the equation $CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$.

B and **C** are incorrect. Neither nitrogen nor oxygen react with water.

D is incorrect. Nitrogen dioxide is not present in the atmosphere to any appreciable extent except when air pollution is present.

Question 18 C

C is correct. This option gives the correct concentration. 0.250 mg in 200 mL is equivalent to 0.125 mg per 100 mL or 1.25 mg per 1000 mL or 1.25 ppm.

A is incorrect. 0.250 mg per 200 mL = 1.25 mg per 1000 mL or 1.25×10^{-3} g L^{-1}.

B is incorrect. 0.250 mg per 200 mL = 0.125 mg per 100 mL = 1.25×10^{-4} g per 100 mL or 1.25×10^{-4} %(m/v).

D is incorrect. 0.250 mg per 200 mL = 1.25×10^{-3} g L^{-1} $= \frac{1.25 \times 10^{-3}}{19.0} = 6.58 \times 10^{-5}$ mol L^{-1}.

Question 19 D

D is correct. The equivalence point is at pH 7. The initial pH of 1 increases slowly as more base is added. The final pH is greater than 12.5 and there is a sharp endpoint. These factors are indicative of a strong acid being titrated with a strong base.

A is incorrect. For a weak acid and a weak base titration, much more gradual pH changes would be expected and the initial pH and final pH would be closer to either side of 7.

B is incorrect. A weak acid would have a higher initial pH, and the pH at equivalence would be greater than 7 due to the presence of the conjugate weak base.

C is incorrect. A weak base would have a lower final pH, and the pH at equivalence would be less than 7 due to the presence of the conjugate weak acid.

Question 20 C

C is correct. The reaction is represented by the equation $Zn(s) + Ni^{2+}(aq) \rightarrow Zn^{2+}(aq) + Ni(s)$. The Zn strip would dissolve, decreasing in mass.

A is incorrect. The Ni^{2+} is reacting and so the green color would become lighter.

B is incorrect. Zn is a sufficiently strong reductant to reduce Ni^{2+}.

D is incorrect. Zinc nitrate is a soluble salt.

SECTION B

Question 1 (13 marks)

a. Pd < Cr < La < Ba 1 mark

Note: The rule is that a more reactive metal will displace a less reactive metal from a solution of its ions, and so Pd must be the least reactive metal while Ba is the most reactive.

b. **i.** $2Cr(s) + 3Pd^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Pd(s)$ 2 marks

1 mark for correct reactants and products.
1 mark for correct balancing and state symbols.

ii. $Ba(s) \rightarrow Ba^{2+}(aq) + 2e^{-}$ 1 mark

c. **i.** Absorbance of 0.25 corresponds to 0.18 mg $L^{-1.}$ 1 mark

As the waste liquid was diluted ×100, undiluted water has a Cr concentration of 18 mg L^{-1}. 1 mark

In 1.0 L, $n\left(Cr\right) = \frac{m}{M} = \frac{18 \times 10^{-3}}{52.0} = 3.46 \times 10^{-4} \text{ mol L}^{-1} = 3.5 \times 10^{-4} \text{ mol L}^{-1}$. 1 mark

ii. m(Cr) in 500 L of waste liquid = 18 × 500 = 9000 mg = 9.0 g 1 mark

iii. $n\left(Cr\right) = \frac{m}{M} = \frac{10.0}{52.0} = 0.1923 \text{ mol}$ 1 mark

$n(Cr(OH)_3 = n(Cr)$ 1 mark

$m(Cr(OH)_3) = n \times M = 0.1923 \times (52.0 + 51.0) = 19.8$ g 1 mark

iv. Settling the precipitate would be less energy-intensive and time-consuming than filtration. 1 mark

The uncontaminated liquid could be siphoned off, and the precipitate allowed to dry for safe disposal. 1 mark

Question 2 (9 marks)

a. **i.** hydrogen ion concentration = $10^{-pH} = 10^{-3.9} = 1.3 \times 10^{-4}$ M 1 mark

ii. $pH = -\log[H^{+}] = -\log(1.0 \times 10^{-3}) = 3$ (*strong acid completely ionised*) 1 mark

b. **i.** $Zn(s) + 2H^{+}(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$ 2 marks

1 mark for correct reactants and products.
1 mark for correct balancing and state symbols.

ii. $2CH_3COOH(aq) + K_2CO_3(s) \rightarrow 2CH_3COOK(aq) + CO_2(g) + H_2O(l)$ 2 marks

1 mark for correct reactants and products.
1 mark for correct balancing and state symbols.

iii. $2HCl(aq) + MgO(s) \rightarrow MgCl_2(aq) + H_2O(l)$ 2 marks

1 mark the correct reactants and products.
1 mark for correct balancing and state symbols.

c. A salt is a compound formed from a metal cation and an anion. 1 mark

Question 3 (11 marks)

a. A contaminant is a substance that is present, which is not normally present or should not be present, in the solid, liquid or gas being considered. 1 mark

b. *For example, any two of:*

- Samples should be taken at various locations and depths.
- Replicate samples should be taken at each site of sampling.
- Samples should be taken using sterile equipment.
- Samples should be transferred immediately to sterile containers with appropriate labels and then the containers should be sealed securely.
- Samples should be stored and transported in a secure and safe manner to the laboratory for analysis.

2 marks

c. **i.** $n(\text{AgCl}) = \frac{m}{M} = \frac{0.0126}{143.4} = 8.7866 \times 10^{-5}$ mol 1 mark

$n(\text{NaCl}) = n(\text{AgCl})$

$m(\text{NaCl}) = n \times M = 8.7866 \times 10^{-5} \times 58.5 = 5.1402 \times 10^{-3}$ g 1 mark

This mass is in 10.0 L, so $c(\text{NaCl}) = 5.14 \times 10^{-4}$ g L^{-1}. 1 mark

ii. *For example, any one of:*

- It was assumed that chloride ions were the only ions present in the sample that reacted with silver ions and so the amount of silver chloride, AgCl, precipitate could be used to calculate the NaCl concentration.
- It was assumed that all chloride ions present in the sample precipitated.

1 mark

iii. *For example, any one of:*

- The electrical conductivity of a sample of the drain water could be compared with the conductivities of samples of known NaCl concentration.
- Atomic absorption spectroscopy (AAS) could be used to determine the sodium ion concentration in the sample.

1 mark

d. **i.** The retention time of ANTU is 5 minutes in the first HPLC output (Graph 1). 1 mark

As there is no peak at 5 minutes in the second HPLC output (Graph 2), it is reasonable to conclude that the drain water does not contain ANTU. 1 mark

ii. *For example:*

Each different compound interacts differently with the HPLC column and solvent. As there are five peaks in Graph 2, there are at least five different compounds present in the drain water sample. 1 mark

Question 4 (15 marks)

a. **i.** Ionic bonds in the potassium nitrate solid are broken. 1 mark

Hydrogen bonds between water molecules are broken. 1 mark

Ion–dipole attraction between the ions and the polar water molecules are formed. 1 mark

ii. Reading from the solubility curve, at 50°C, the solubility is 100 g in 100 g of water or 100 g in 100 mL of water (assuming a density of 1 g mL^{-1}). Therefore, there is 40 g of solute in 40 mL of saturated solution. 1 mark

At 40°C, the solubility is 75 g in 100 mL of water, and so there is $\frac{75}{100} \times 40 = 30$ g per 40 mL of solution. 1 mark

Therefore, (40 – 30) = 10 g of potassium nitrate crystallises. 1 mark

iii. There is 40 g of solute in 40 mL of saturated solution. Adding 10 mL of water means that there is 40 g of solute in 50 mL of solution. 1 mark

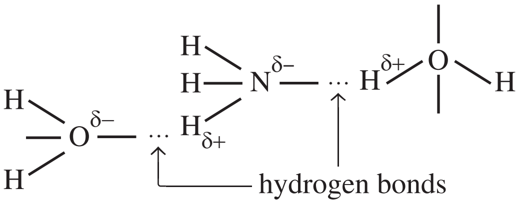
40 g of solute in 50 mL of solution = 80 g in 100 mL, and so the temperature can be lowered to a minimum of 42°C *(reading from the solubility curve)* for the solution to remain saturated. 1 mark

Note: Accept values in the range 41–43°C.

b. There is some polarity at the hydroxyl end of the hexanol molecule, but the long hydrocarbon chain is non-polar. *(As the chain length increases, overall polarity decreases.)* 1 mark

Hydrogen bonding between water molecules will not be broken because most of the hexanol molecule is non-polar and so will not be held in solution by water molecules. 1 mark

c. **i.** Ammonia (NH_3) is a small molecule that has a nitrogen atom bonded to hydrogen atoms with highly polar covalent bonds. NH_3 molecules form intermolecular hydrogen bonds with water molecules, resulting in its high solubility. 1 mark



2 marks

1 mark for the correct molecular structures.

1 mark for correctly drawn and labelled hydrogen bonds.

ii. The experiment relies on the gas in the round flask being completely dissolved in the water that is squirted into the flask, thus lowering the gas pressure. 1 mark

Oxygen (O_2) gas has very low solubility in water and so much of the O_2 gas will remain in the round flask, meaning that the fountain effect would not occur. So, O_2 gas could not be used in place of NH_3 gas. 1 mark

Question 5 (7 marks)

a. $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$ 2 marks

1 mark for the correct reactants and products.
1 mark for correct balancing and state symbols.

b. $[H_3O^+] = 10^{-pH} = 10^{-3.7}$

$K_w = [H_3O^+][OH^-] = 7.29 \times 10^{-14}$ 1 mark

$10^{-3.7} \times [OH^-] = 7.29 \times 10^{-14}$

$[OH^-] = 3.7 \times 10^{-10}$ M 1 mark

c. **i.** As the pure water is heated, the value of K_w increases, and so $[H_3O^+]$ increases because in pure water $[H_3O^+] = [OH^-]$ and $K_w = [H_3O^+]^2$. 1 mark

As $[H_3O^+]$ increases, the pH of the water decreases. 1 mark

ii. neutral 1 mark

Note: For pure water at any temperature, $[H_3O^+] = [OH^-]$ and so the water remains neutral.