



# **Units 3 and 4 Chemistry**

## **Practice Exam Solutions**

Stop!

Don't look at these solutions until you have attempted the exam.

Any Questions?

Contact Engage at [info@ee.org.au](mailto:info@ee.org.au)

## Section A – Multiple-choice questions

### Question 1

The correct answer is D.

- Stem from longest chain containing the double bond: hept- (7)
- Double bond origin at first carbon: hept-1-ene
- 3-carbon substituent at C3, 1-carbon substituent at C5: 3-propyl and 5-methyl
- List substituents in alphabetical order: **5-methyl-3-propylhept-1-ene**

### Question 2

The correct answer is C.

- Oxidation number of S in  $\text{H}_2\text{S}_2\text{O}_3$  is +2 (H is +1 with non-metals; O is -2; sum of all oxidation states must add to 0 in neutral compound).
- Because H(+1), O(-2), Cl (-1) and F(-1) in compounds above, oxidation state of S in options A, B, C and D is +4, +5/2, +2 and +5 respectively.
- Therefore, option (c) is the only one with matching oxidation number.

### Question 3

The correct answer is B.

- Starting pH of 11 indicates that initial reactant is a weak base.
- pH at equivalence point is approximately pH 5 – because pH at equivalence point is below 7, it must be reaction between weak base and strong acid.

### Question 4

The correct answer is A.

- From graph, it is possible that any indicator that changes form/colour between pH 3 and 7 may be appropriate, due to sharp end point at approximately pH 5.
- Using VCE Chemistry Data Book, the indicators in options (b), (c), (d) all fall within this range, whereas Thymol Blue has a range from 1.2-2.8; hence not appropriate.

### Question 5

The correct answer is C.

- Esterification requires reaction between a primary alkanol and a carboxylic acid, therefore answer must be C: propan-1-ol (it is the only primary alkanol present)
- Confirmed by naming the original carboxylic acid:
  - Longest chain: – hexanoic acid
  - Methyl group attached to the 4<sup>th</sup> carbon (the carbon in the carboxyl group must be numbered 1) – 4-methylhexanoic acid

### Question 6

The correct answer is B.

- To form biodiesel, triglycerides from animal fats or plant oils are hydrolysed into fatty acids and glycerol, and the fatty acids then react with small alkanols (usually methanol or ethanol) to form esters.
- This is catalysed by sodium hydroxide, or another strong base.
- Therefore glycerol is a product, not a reactant/catalyst.

**Question 7**

The correct answer is A.

- Immediately rule out (b) (is a base so would decrease hydronium concentration) and (c) (has a smaller  $K_a$  than HF; because they are equimolar, this means HF have a greater hydronium concentration due to greater extent of ionisation).
- Complete ionisation of HCl as strong acid, therefore  $[H_3O^+] = [HCl]$ , and so concentration is 0.1 M
- For HF:  $K_a = \frac{[F^-][H_3O^+]}{[HF]} \rightarrow 7.6 \times 10^{-4} = \frac{[H_3O^+]^2}{1.0} \rightarrow [H_3O^+] = 2.8 \times 10^{-2} M$
- Therefore, HCl has the highest hydronium concentration.

**Question 8**

The correct answer is B.

- (d) is correct procedure, will not result in change.
- (a) and (c) are both erroneous procedures that would require a greater volume of HCl to neutralise the NaOH, which would lead to its calculated concentration being less than the actual.
- (b) may dilute the NaOH in the pipette, which means less HCl would be required to neutralise it, and so the concentration of the HCl would be calculated to be higher than the actual.

**Question 9**

The correct answer is C.

- Mass spectrometry can be used to detect the relative abundances of ions of a particular mass in a sample, so would be most suitable for detecting the amounts of the isotopes present.

**Question 10**

The correct answer is D.

- Converting to appropriate units gives  $P = 101.3 \text{ kPa}$ ,  $V = 1.982 \text{ L}$ , and  $T = 297 \text{ K}$ ; recall that  $R = 8.314 \text{ J/K/mol}$ .
- $pV = nRT \rightarrow 101.3 \times 1.982 = n \times 8.314 \times 297 \rightarrow n = 0.0813 \text{ mol}$
- Thus, molar mass of gas is equal to  $M = \frac{m}{n} = \frac{2.44}{0.0813} = 30.0 \text{ g/mol}$
- Therefore, answer is (d), as NO is the only option with molar mass of 30.0 g/mol.

**Question 11**

The correct answer is B.

- Peptide (amide) linkages are covalent linkage group that are responsible for maintaining the primary structure of the protein, not tertiary.
- The other three options are all responsible for determining the tertiary structure.

**Question 12**

The correct answer is B.

- The second reaction is anaerobic respiration in yeast; that is, fermentation of glucose to ethanol and carbon dioxide in the absence of oxygen.
- (a), (c) and (d) are aerobic respiration, anaerobic respiration in animals and photosynthesis respectively.

**Question 13**

The correct answer is C.

- The question is essentially asking which fatty acid has the highest proportion, or amount, of C=C double bonds in the alkyl chain (both interpretations will lead to the correct answer).
- Using the VCE Chemistry Data Book, can use the general formula for saturated fatty acids,  $C_nH_{2n+1}COOH$ , in addition to the knowledge that each double bond results in two less hydrogens, to calculate that arachidonic acid has four C=C double bonds, whereas the other options either have none or one.

**Question 14**

The correct answer is **BA**.

- The structure of dimethylpropan-1-ol:
- All H's in the three methyl groups are equivalent; ~~only~~ the H in the hydroxyl group has a unique environment and the other H's attached to the same C also have a unique environment. Therefore, there are ~~three~~ distinct peaks in the low-res  $^1\text{H}$  NMR spectrum.
- The three C's in the methyl groups attached to the central carbon are equivalent; the central carbon and the terminal carbon attached to the hydroxyl group both have unique bonding environments. Therefore, there will be three peaks in the  $^{13}\text{C}$  NMR spectrum.

### Question 15

The correct answer is C.

- Carboxylic acids are formed by the oxidation of primary alkanols in the presence of a strong oxidant such as acidified potassium permanganate or acidified potassium dichromate.

### Question 16

The correct answer is D.

- (a) and (b) are possibly both acceptable, contributing explanations.
- (c) is unrelated to rate, and is also an inaccurate statement.
- The **best** explanation is (d), as the effect of this is that there is an increased proportion of 'successful collisions', which contributes more significantly to increased rate of reaction than simply a higher frequency of collisions in total.

### Question 17

The correct answer is A.

- Must be written as products over reactants.
- Solid reagents are not to be included (as they do not have a 'concentration').

### Question 18

The correct answer is B.

- Reaction is exothermic, therefore increasing temperature will decrease yield.

### Question 19

The correct answer is C.

- Catalysts act by decreasing the activation energy barrier for an equilibrium system.
- Therefore, due to the lower energy threshold, the rates of both the forward and back reactions increase.

### Question 20

The correct answer is C.

- $\Delta H$  is the difference in energy between the reactants and the products
- From graph, can be seen that difference is 276 kJ/mol
- Positive sign confirmed by an overall increase in energy (endothermic)

### Question 21

The correct answer is B.

- $E_A = 473 - 276 = 196 \text{ kJ/mol}$

### Question 22

The correct answer is C.

- $[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-7.8} = 1.585 \times 10^{-8} \text{ M}$
- $[\text{H}_3\text{O}^+][\text{OH}^-] = 10^{-14} \rightarrow [\text{OH}^-] = \frac{10^{-14}}{[\text{H}_3\text{O}^+]} = 6.3 \times 10^{-7} \text{ M}$

### Question 23

The correct answer is A.

$$\bullet \quad CF = \frac{VIt}{\Delta T} = \frac{7.45 \times 3.20 \times 23.4}{0.45} = 1239.68 \cong 1240$$

**Question 24**

The correct answer is D.

- $Energy = CF \times \Delta T = 1239.68 \times 0.780 = 966.95$
- $\Delta H = \frac{energy}{n} = \frac{966.95}{0.0035} = 276271.5 \text{ J} = 276 \text{ kJ}$
- Combustion reaction, therefore  $\Delta H$  must be negative (i.e. energy released)

**Question 25**

The correct answer is D.

- Because the  $\text{Cu}^{2+}/\text{Cu}$  half equation is significantly higher on the electrochemical series, it will proceed spontaneously as a reduction reaction (forwards), whilst the  $\text{Al}^{3+}/\text{Al}$  half equation (backwards).
- Electrons lost and gained must be balanced, so copper half equation must be multiplied by 3 and aluminium half equation must be multiplied by 2 in order to achieve this.

**Question 26**

The correct answer is D.

- The question states that the galvanic cell was set up at  $35^\circ\text{C}$ .
- The electrochemical series is accurate for reactions at standard conditions, which includes a temperature of  $25^\circ\text{C}$  – where the temperature deviates, the values half-cell potentials listed in the series are no longer applicable/accurate.
- Thus, the potential difference for the cell cannot be determined here without further information.

**Question 27**

The correct answer is B.

- The internal circuit of a galvanic cell refers to the flow of ions through the salt bridge in order to conserve charge in the half-cells

**Question 28**

The correct answer is A.

- Water is a stronger oxidant than  $\text{Ca}^{2+}$ , and so would reduce preferentially to it at the cathode of an electrolytic cell, thus calcium would not be produced.
- Therefore, a molten electrolyte (hence no water present) is required.
- The other metals listed are all stronger oxidants than water.

**Question 29**

The correct answer is C.

- Methane can be generated from the decay of organic material in the presence of oxygen; hence it is renewable
- The other three options are either non-renewable/finite, or are unable to be replenished at a rate sufficient to keep up with the rate of consumption.

**Question 30**

The correct answer is B.

- $t$  in seconds =  $(83 \times 60) + 20 = 5000 \text{ s}$
- $Q = I \times t = 135.1 \times 5000 = 675\,550 \text{ C}$
- $Q = n(e^-) \times F \rightarrow n(e^-) = Q \div F = 675\,550 \div 96\,500 = 7 \text{ mol}$
- Charge on metal is  $2+$ , therefore two electrons consumed for every one mole of metal formed; therefore,  $n(\text{metal}) = 7 \div 2 = 3.5 \text{ mol}$
- $M(\text{metal}) = m \div n = 85.05 \div 3.5 = 24.3 \text{ g/mol}$
- Thus metal is Magnesium (Mg.)

## Section B – Short-answer questions

Marks allocated are indicated by a number in square brackets, for example, [1] indicates that the line is worth one mark.

### Question 1a

- Weak base [1 mark]
- Initial pH 11, therefore weak base [1 mark]
- pH at equivalence point is below 7, therefore strong acid/weak base rxn [1 mark]

### Question 1b

- Equivalence point: the point in the titration when the reactants have been mixed exactly according to the mole ratios in the equation (or any equivalent explanation) [1 mark]
- End point: The point in the titration when the indicator changes colour [1 mark]

### Question 1c

- Methyl red [1 mark] – from Data Book, only indicator with a range that includes pH 5.5

### Question 1d

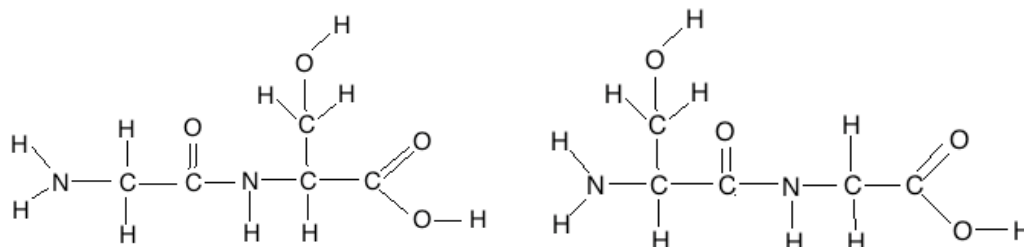
- $n(\text{HCl}) = c \times V = 1.00\text{M} \times 0.0200\text{L} = 0.0200\text{mol}$  [1 mark]
- $n(\text{HCl}) = n(\text{XOH})$  because they react 1:1 [1 mark]
- $c(\text{XOH}) = \frac{n}{V} = \frac{0.0200}{0.0450} = 0.444\text{M}$ , to 3 sig figs [1 mark]

### Question 1e

- Would dilute HCl slightly [1 mark]
- Therefore would require greater volume of HCl to neutralise base [1 mark]
- Thus, given fixed volume, calculated concentration of base would be higher than actual [1 mark]

### Question 2a

1 mark for each of the structures below, if complete and correct



### Question 2b

- 1 mark for circling  $-\text{CONH}-$  group and labelling 'peptide' (amide also accepted)
- 1 mark for circling  $\text{H}_2\text{N}-$  group and labelling 'amine' or 'amino'
- 1 mark for circling  $-\text{COOH}$  group and labelling 'carboxyl'

### Question 2c

- Condensation polymerisation or condensation; water ( $\text{H}_2\text{O}$ ) [1 mark]
- Must correctly identify both to gain the mark

### Question 2d

- Amino group acts as a base, accepts proton from water molecule (nitrogen attached to three hydrogens, gains positive charge) [1 mark]
- Carboxyl group acts as acid, donates proton to water molecule (forms  $-\text{COO}^-$  group) [1 mark]

**Question 3a**

Le Chatelier's Principle is that when an equilibrium system is subjected to a change, the system will adjust to partially oppose the change's effect (1 mark – wording is flexible, but must reference *equilibrium*, *change*, and *partially oppose/offset/etc.*)

**Question 3b**

i.

- Increase in energy of system; system will respond by favouring reaction that consumes energy (1 mark)
- Because system is exothermic, favours the reverse reaction (or position of equilibrium shifts to left), therefore ethanol yield decreases [1 mark]

ii.

- Increase in volume is decrease in pressure; system will respond by favouring reaction that will cause increase in pressure [1 mark]
- Greater relative number of moles of gas on products side as opposed to reactants, therefore system will favour the forward reaction (or position of equilibrium shifts to right), therefore ethanol yield increases [1 mark]

iii.

- Argon is an inert gas (addition of an inert/unreactive gas does not alter partial pressures of gases in the system). No change = no effect on yield [1 mark]

**Question 3c**

i.

Advantages may include (1 mark each for any two):

- Derived from carbohydrates found in plant material, so can be considered 'renewable'.
- Generally uses waste material left over after food production, therefore helping to reduce wastage.
- Uses readily available raw materials (plant material), so less likely to be influenced by political/economic problems associated with importing raw materials.
- Much closer to being 'carbon neutral' than conventional fossil fuels, as the carbon dioxide released is equal to the carbon dioxide consumed by the plants from which it is derived during photosynthesis (although some carbon dioxide emissions from fossil fuel are still required to power the process to produce the ethanol).

ii.

Disadvantages may include (1 mark for any one):

- Possibility of 'energy crops' reducing the amount of land available for agriculture/food crops, possibility stimulating a food shortage or strain.
- Environmental issue of waste disposal of fermentation liquors
- Less efficient than petroleum; has a lower heat of combustion per unit mass
- Many current engines/machinery would require modification to be able to use ethanol as a fuel source

**Question 4a**

i.

- Only one unique hydrogen bonding environment (1 mark)
- Either  $\text{CH}_3\text{COOR}$  or  $\text{CH}_3\text{COR}$  (see Data Book) (1 mark)

ii.

- Two unique carbon bonding environments (1 mark)
- An  $\text{R-CH}_3$  and an  $\text{RCOOH}$  or similar (1 mark)

iii.

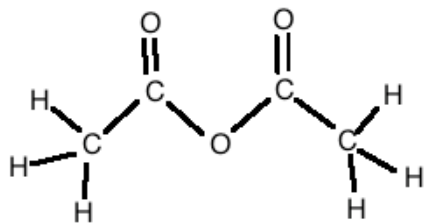
- Molecular ion peak at  $m/z=102$ , therefore relative molecular mass of 102 (1 mark)
- Base peak (or a strong peak) at  $m/z=43$ , therefore there is a common fragment formed with a relative molecular mass of 43 (1 mark)

iv.

- Strong peaks at around  $1100$ ,  $1300$ ,  $1750\text{ cm}^{-1}$  indicative of  $\text{C-C}$ ,  $\text{C-O}$ , and  $\text{C=O}$  groups (2 marks for all three, 1 mark for identifying two)
- Absence of peak at  $2500\text{-}3300$  and  $3200\text{-}3550$  suggests no  $\text{O-H}$  groups (if identified only two of the above groups, can gain second mark with this observation)

**Question 4b**

(b) 2 marks awarded for correct structure (acetic anhydride)

**Question 5a**

i.

- Addition (or hydrolysis) [1 mark]

ii.

- Oxidation [1 mark]

iii.

- Esterification (or condensation) [1 mark]

**Question 5b**

i.

Water (reactant) and phosphoric acid (catalyst) [1 mark each]

ii.

- Acidified potassium dichromate or acidified potassium permanganate catalyst [1 mark for either one of these]

iii.

- Concentrated sulphuric acid catalyst [1 mark]

**Question 5c**

- Propyl propanoate [1 mark]

**Question 5d**

i.

- Infrared radiation provides molecules with an amount of energy that causes them to vibrate due to stretching and bending of covalent bonds [1 mark]
- Infrared radiation spectroscopy provides information about the functional groups and types of bonds present in a molecule [1 mark]

ii.



- The presence/absence of a peak at either one of 2500-3300  $\text{cm}^{-1}$  or 3200-3550  $\text{cm}^{-1}$ , indicating O-H (acid) and O-H (alcohols) respectively. [1 mark]
- If peak present, reactant (either propanoic acid or propan-1-ol, depending on choice) still present, and so reaction has not proceeded to completion; conversely, if peak not present, than all reactant has been converted. [1 mark]

**Question 6a**

- $E = VIt$  and  $Q = It$ , therefore  $E = QV$  [1 mark]
- Therefore,  $Q = \frac{E}{V} = \frac{518\,400\text{ J}}{6.40\text{ V}} = 81\,000\text{ C}$  [1 mark]
- $Q = n(e^-) \times F \rightarrow n(e^-) = \frac{Q}{F} = \frac{81\,000}{96\,500} = 0.8394\text{ mol}$  [1 mark]
- $n(\text{Na}) = n(e^-)$  because sodium ion has a charge of 1+, so one electron gained for every Na atom produced [1 mark]
- $m(\text{Na}) = M \times n = 23.0 \times 0.8394 = 19.3\text{ g}$  [1 mark]
- 1 mark for 3 sig figs and units correct throughout

**Question 6b**

If water were present, it would be reduced preferentially to sodium at the cathode [1 mark] and so no metal would form [1 mark].

**Question 6c**

1 mark for each point (a similar process with a different, but still correct, precipitate will be accepted)

- Weigh sample, blend/filter so that all chloride ions from sample are in solution
- Add excess of  $\text{AgNO}_3$  to precipitate chloride ions as insoluble  $\text{AgCl}$
- Filter and collect the precipitate
- Wash with small volume of water and dry to constant mass at  $\sim 110^\circ\text{C}$
- Weigh  $\text{AgCl}$  sample
- Use mass to perform stoichiometric calculations to determine the molar amount of chloride present (hence  $\text{NaCl}$ ), can then calculate concentration

**Question 7a**

- $\text{C}_2\text{H}_6(\text{g}) + \text{Cl}_2(\text{g}) \xrightarrow{\text{UV light OR heat}} \text{C}_2\text{H}_5\text{Cl}(\text{g}) + \text{HCl}(\text{g})$
- 1 mark for reactants/products all correct, 1 mark for both states and condition

**Question 7b**

- $K = \frac{[\text{C}_2\text{H}_5\text{Cl}][\text{HCl}]}{[\text{C}_2\text{H}_6][\text{Cl}_2]}$  [1 mark]

**Question 7c**

2 marks for determining n of all species at equilibrium

- $n(\text{C}_2\text{H}_6) = 0.340 - 0.1114 = 0.2286\text{ mol}$
- $n(\text{Cl}_2) = 0.780 - 0.1114 = 0.6686\text{ mol}$
- $n(\text{C}_2\text{H}_5\text{Cl}) = n(\text{HCl}) = 0.1114\text{ mol}$

1 mark for converting all to concentrations by dividing moles by volume (4.00 L)

- $[\text{C}_2\text{H}_6] = 0.05715\text{ M}$ ;  $[\text{Cl}_2] = 0.16715\text{ M}$ ;  $[\text{C}_2\text{H}_5\text{Cl}] = [\text{HCl}] = 0.02785\text{ M}$

1 mark for correct value of K

- $K = \frac{[\text{C}_2\text{H}_5\text{Cl}][\text{HCl}]}{[\text{C}_2\text{H}_6][\text{Cl}_2]} = \frac{0.02785 \times 0.02785}{0.05715 \times 0.16715} = 0.0812$

**Question 7d**

- Catalyst provides an alternative reaction pathway that reduces activation energy [1 mark]
- This results in a higher proportion of 'successful' collisions between reactant particles, in which particles collide with energy sufficient to overcome the activation energy barrier [1 mark]
- Consequently, the rate of both the forward and back reactions increase, so equilibrium is reached more quickly. [1 mark]

- Presence of a catalyst has no effect on value of equilibrium constant, therefore it does not result in any change to ultimate yield of the reaction. [1 mark]

**Question 8**

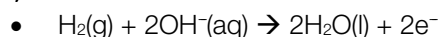
- Molar volume at STP = 22.4 L/mol
- $n(H_2) = \frac{V}{V_m} = \frac{3.410 L}{22.4 L/mol} = 0.1522 mol$  [2 marks]
- $n(H_2) = n(Cu)$  because they react 1:1,  $\therefore n(Cu) = 0.1522 mol$  [1 mark]
- $m(Cu) = M \times n = 63.5 \times 0.1522 = 9.6647 g$  [1 mark]
- $\% w/w (Cu) = \frac{9.6647}{10.5} \times 100 = 92.0 \%$  [1 mark]

**Question 9a**

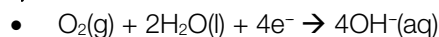
- Fuel cells convert energy directly from chemical  $\rightarrow$  electrical [1 mark]
- Energy from combustion of fossil fuels is transferred from chemical  $\rightarrow$  thermal  $\rightarrow$  mechanical  $\rightarrow$  electrical [1 mark]
- Energy is lost at each stage of conversion, so the less conversions, the more efficient the energy transfer [1 mark]

**Question 9b**

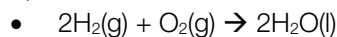
i)



ii)



iii)

**Question 9c**

- A primary cell has a fixed/limited initial amount of reactants [1 mark]
- A fuel cell requires a continuous supply of reactants [1 mark]

**Question 9d**

1 mark each for any two of the following

- Require constant fuel supply
- Expensive to develop and manufacture
- Some require expensive electrolytes or catalysts
- Effectiveness affected by impurities in hydrogen fuel
- Generate DC current, most household/industry appliances rely on AC current
- Not efficient fuel source for transport vehicles due to lack of filling stations able to provide hydrogen fuel, would require large-scale construction of means of storage and distribution