Paper 1 Worked Solutions

1	**A**	**2**	**B**	**3**	**D**	**4**	**D**	**5**	**B**
6	**B**	**7**	**A**	**8**	**A**	**9**	**B**	**10**	**A**
11	**C**	**12**	**B**	**13**	**C**	**14**	**D**	**15**	**D**
16	**B**	**17**	**B**	**18**	**C**	**19**	**A**	**20**	**C**
21	**D**	**22**	**C**	**23**	**B**	**24**	**C**	**25**	**A**
26	**D**	**27**	**B**	**28**	**B**	**29**	**D**	**30**	**A**

1 Bearing in mind the mole ratio of the three gases when writing the balanced equation, you should be able to conclude that 1 mole of $Ca(NO_3)_2$ requires 3 moles of C:

$$Ca(NO_3)_2 + 3C \rightarrow CaO + 2CO_2 + CO + Z$$

It should also be clear that all the number of O atoms on both sides of the equation are already equal (i.e. balanced), and thus Z have to be N_2 so that the number of N atoms (the only remaining element to be balanced) on both sides are equal:

$$Ca(NO_3)_2 + 3C \rightarrow CaO + 2CO_2 + CO + \mathbf{N_2}$$

Answer: **A**

2

A: $A_r = \dfrac{91.1(28)+7.9(29)+1.0(30)}{100} = 28.099$

B: $A_r = \dfrac{92.2(28)+4.7(29)+3.1(30)}{100} = 28.109$

C: $A_r = \dfrac{95.0(28)+3.2(29)+1.8(30)}{100} = 28.068$

D: $A_r = \dfrac{96.3(28)+0.3(29)+3.4(30)}{100} = 28.071$

Answer: **B**

3 To get the balanced equation:

$$H_2S(aq) \rightarrow S(s) + 2H^+(aq) + 2e^- \ (\times 2)$$
$$\underline{SO_2(aq) + 4H^+ + 4e^- \rightarrow S(s) + 2H_2O(l)}$$
$$2H_2S(aq) + SO_2(aq) \rightarrow 3S(s) + 2H_2O(l)$$

Dividing throughout by 3, we get:

$$\frac{2}{3}H_2S(aq) + \frac{1}{3}SO_2(aq) \rightarrow S(s) + \frac{2}{3}H_2O(l)$$

Answer: **D**

4 For ^{10}B: number of protons = 5;
number of neutrons = 10 − 5 = 5
⇒ ratio of proton : neutron = 1 : 1

A: ^{40}Ar: number of protons = 18;
number of neutrons = 40 − 18 = 22
⇒ ratio of proton : neutron = 9 : 11

B: ^{40}K: number of protons = 19;
number of neutrons = 40 − 19 = 21
⇒ ratio of proton : neutron = 19 : 21

C: ^{32}P: number of protons = 15;
number of neutrons = 32 − 15 = 17
⇒ ratio of proton : neutron = 15 : 17

D: ^{32}S: number of protons = 16;
number of neutrons = 32 − 16 = 16
⇒ ratio of proton : neutron = 1 : 1

Answer: **D**

5 Around the S-atom, there are 3 bond pairs and 1 lone pair of electrons (a double bond is considered one bond pair).
By VSEPR theory, the four electron pairs will space themselves as far apart as possible to minimise repulsion, leading to an electronic geometry of tetrahedral, and a bond angle of 109°. However, as the lone pair-bond pair repulsion are stronger than bond pair-bond pair repulsion, the bond angle will be smaller than 109°, ⇒ approximately 107°.

Answer: **B**

6 In order for the anion to have a square pyramidal shape, it must have 5 bond pairs and 1 lone pair of electrons. Since Sb is from group 15, it has 5 valence electrons, which are used to form normal single bond with the five F-atoms (i.e. 5 bond pairs). Hence Sb must receive **two electrons** from external sources, in order to have one lone pairs of electrons.
⇒ n = 2, i.e. the anion is SnF_5^{2-}.

Answer: **B**

7 Since both butane and methane are made up of non-polar molecules, only id-id interactions exist between their respective molecules. As butane has more electrons than methane, its electron cloud is more polarisable, and so the instantaneous dipole-induced dipole interactions between its molecules are stronger, and hence it is easier to liquify butane than methane.

Answer: **A**

8 $L.E. = \left|\frac{q_+ \times q_-}{r_+ + r_-}\right|$

Cationic radii: $Li^+ < Na^+$
Anionic radii: $O^{2-} < S^{2-}$
sodium sulfide, Na_2S, has the least exothermic lattice energy while lithium oxide, Li_2O, has the most exothermic lattice energy.

Answer: **A**

9 Bond breaking: 2(C−H) +6(C−C*l*) + (O=O)
= 2(+410)+6(+340)+(+496)
= +3356 kJ mol^{-1}
Bond forming: 2(C=O) +4(C−C*l*) + 2(H−C*l*)
=2(−740)+4(−340)+2(−431)
=−3702 kJ mol^{-1}
ΔH = (+3356) + (−3702) = −346 kJ mol^{-1}

Answer: **B**

10 For the first pair of acid and base, we learnt that ΔH for a strong acid (HC*l*) and a strong base (NaOH) is −57.0 kJ mol^{-1}.

Since the magnitude of ΔH for the second pair of acid and base is smaller than 57.0 kJ mol^{-1}, a weak acid must have reacted with NaOH.
⇒ P must be ethanoic acid (option **A** or **B**).

Since the magnitude of ΔH for the third pair of acid and base is smaller than 57.0 kJ mol^{-1}, HC*l* must have reacted with a weak base.
⇒ Q must be ammonia (option **A** or **C**).

Since ΔH for the fourth pair of acid and base is also − 57.0 kJ mol^{-1}, nitric acid must have reacted with a strong base.
⇒ R must be potassium hydroxide (option **A** or **C**).

Answer: **A**

11 Definition of a dynamic equilibrium: an equilibrium where the forward and reverse reactions are continuing at the **<u>same rate</u>** (or that the forward and reverse reaction are taking place, but the rate is not equals to zero).

Answer: **C**

12 When pressure is reduced at constant temperature, equilibrium position will shift to the side with <u>a larger number of moles of gases</u> to increase pressure (option **B** or **D**).

When temperature is increased, the endothermic reaction will occur to a greater extent to absorb heat (option **A** or **B**)

Answer: **B**

13 $K_w = [H^+][OH^-]$ (by definition)

At 30 °C, $K_w = 1.44 \times 10^{-14}$ mol^2 dm^{-6}
⇒ $[H^+][OH^-] = 1.44 \times 10^{-14}$

Since $[H^+] = [OH^-]$ for pure water,
⇒ $[H^+]^2 = 1.44 \times 10^{-14}$
⇒ $[H^+] = 1.2 \times 10^{-7}$

pH = −log $[H^+]$ = −log (1.2×10^{-7}) = 6.92 (< 7)

Answer: **C**

14 Catalyst <u>increases</u> the rate constant (options **C** and **D**).

Catalyst lowers the activation energy (all four options).

Catalyst <u>does not alter the energy level of the reactants and the products</u> (options **B** and **D**).

Answer: **D**

15 When [acid] is low, reaction is <u>first order</u> with respect to acid
⇒ <u>rate increases linearly</u> as [acid] increases (options **A** or **D**).

When [acid] is high, reaction is <u>zero order</u> with respect to acid.
⇒ <u>rate remains the same</u> as [acid] increases i.e. the graph approaches a verticlal line (option **D**).

Answer: **D**

16 Number of protons increases from Na^+ to Al^{3+}, and hence nuclear charge increases.

Na^+, Mg^{2+} and Al^{3+} have the same total number of electrons.

As a result, the effective nuclear charge (net electrostatic force of attraction between the nucleus and valence electrons) increases from Na^+ to Al^{3+}, and so ionic radii decreases.

Answer: **B**

17 Since MgO will react with and dissolve in HC*l* (as a soluble salt is formed):

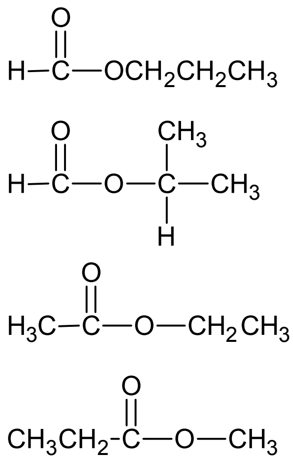
$$MgO + 2HCl \rightarrow MgCl_2 + H_2O$$

and Si will not react with or dissolve in HC*l*. Hence Si can be removed from the solution by filtration. ⇒ Method 1 will work (option **A** or **B**).

Since both MgO and Si have very high melting and boiling points, neither of them will vapourise on gentle heating.
⇒ Method 2 will **<u>not</u>** work (option **B** or **D**).

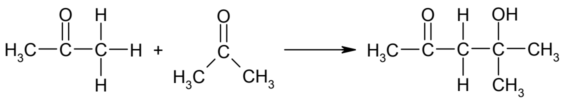
Answer: **B**

18 The four possible isomers with molecular formula $C_4H_8O_2$ are:

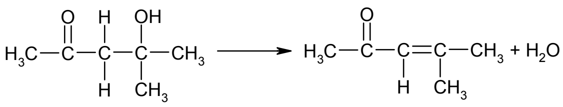


Answer: **C**

19 I is an addition reaction as the first propanone molecule is added across the C=O double bond of the second propanone molecule to produce an alcohol:



II is an elimination reaction as an unsaturated alkene is formed with the elimination of a water molecule from the alcohol:



Answer: **A**

20 **A**: Correct. Since there are 3 bond pair and 0 lone pair of electrons around each of the two C-atoms, the shape around each C-atom is trigonal planar. Hence all two C-atoms and four H-atoms lie on the same plane.

B: Correct. Molecular formula of ethane is C_2H_4, and so the empirical formula (showing the lowest mole ratio) is CH_2.

C: Not correct. As the shape around each C-atom is trigonal planar, the bond angle is 120°.

D: Correct. Each of the two C-atoms forms one σ-bond with two H-atoms (total of four σ-bonds), and there is one σ-bond and one π-bond between the two C-atoms.

Answer: **C**

21 **A**: Incorrect. Both alcohol groups can undergo substitution with PCl_5.

B: Incorrect. Both alcohol groups can undergo elimination of water.

C: Incorrect. Neither alcohols contain the −CH(OH)CH_3 group.

D: Correct. Only one of the alcohol is a secondary alcohol and can be oxidised by $Cr_2O_7^{2-}$; the other is a tertiary alcohol and cannot be oxidised.

Answer: **D**

22 **A**: Incorrect. But-1-ene can be formed from 2-bromobutane by the elimination of HBr using hot ethanolic KOH.

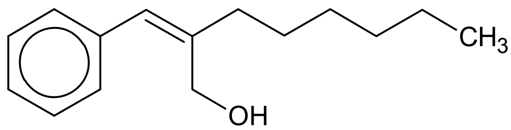
B: Incorrect. Butan-2-ol can be formed from 2-bromobutane by (nucleophilic) substitution using hot NaOH(aq).

C: Correct. A 2-bromobutane cannot be converted to butane in one step.

D: Incorrect. Butan-2-amine can be formed from 2-bromobutane by (nucleophilic) substitution using ethanolic NH_3, heat in sealed tube.

Answer: **C**

23 Only the aldehyde can be reduced by $NaBH_4$ to form a primary alcohol. The C=C is not reduced. The product is shown below:



$C_{15}H_{22}O$

$M_r(C_{15}H_{22}O) = 218$

Answer: **B**

24 **A**: Incorrect. Although CH_2=CHCOCH_2OH can be reduced (using H_2(g), Pt) to form CH_3CH_2CH(OH)CH_2OH - $C_4H_{10}O_2$, and it does not react with Fehling's solution (as it does not contain an aldehyde group), when treated with HCN and NaCN, it will not form $C_6H_8N_2O_2$, as it only has one ketone group (it will form CH_2=CHC(CN)(OH)CH_2OH instead).

B: Incorrect. Although CH_3COCH=CHOH can be reduced (using H_2(g), Pt) to form CH_3CH(OH)CH_2CH_2OH - $C_4H_{10}O_2$, and it does not react with Fehling's solution (as it does not contain an aldehyde group), when treated with HCN and NaCN, it will not form $C_6H_8N_2O_2$, as it only has one ketone group (it will form CH_3C(CN)(OH)CH=CHOH instead).

C: Correct. $CH_3COCOCH_3$ can be reduced to form $CH_3CH(OH)CH(OH)CH_3$ - $C_4H_{10}O_2$, react with HCN and NaCN to form $CH_3C(CN)(OH)C(CN(OH)CH_3$ - $C_6H_8N_2O_2$, and it does not react with Fehling's solution (as it does not contain an aldehyde group)

D: Incorrect. Although CH_3COCH_2CHO can be reduced to form $CH_3CH(OH)CH_2CH_2OH$ - $C_4H_{10}O_2$, react with HCN and NaCN to form $CH_3C(CN)(OH)CH_2CH(CN)OH$ - $C_6H_8N_2O_2$, it will form a brick red ppt with Fehling's solution (as it contains an aldehyde group)

Answer: **C**

25 **A**: Incorrect. Although artemisinic acid have two C=C double bond, it is not able to exhibit geometric (cis-trans) isomerism. This is because one of the C=C is within a ring (⇒ the two carbon groups that are part of the ring, must be placed in the cis-position relative to each other), and for the other C=C, there are two H-atoms on one of the C-atom.

B: Correct. As artemisinic acid have a carboxylic acid group, it can react with ethanol to form an ester with (with conc H_2SO_4 as a catalyst).

C: Correct. Artemisinic acid have a molecular formula of $C_{15}H_{22}O_2$.

D: Correct. As artemisinic acid have two alkene functional groups, it can undergo mild oxidation with cold dilute MnO_4^- to form diols.

Answer: **A**

26 **1**: Correct: $-134 = \Delta H_{R\to T} + (-75) - (+92)$

$\Delta H_{R\to T} = (-134) + 75 + 92 = +33 \text{ kJ mol}^{-1}$

2: Incorrect. $\Delta H_{T\to S} = (-75) - (+92)$

$= -167 \text{ kJ mol}^{-1}$ (exothermic)

3: Incorrect. From **S** → **U**, 92 kJ of energy is absorbed per mole of reaction.
⇒ **U** has a higher energy content than **S**.

Answer: **D**

27 **1**: Correct statement.

2: Correct statement.

3: Incorrect. **Units of rate constant = (mol dm^{-3})$^{1-n}$ s^{-1}**
(where n= overall order of reaction)

Answer: **B**

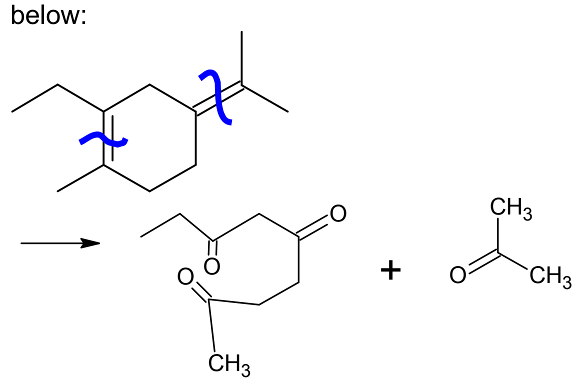
28 The chloride of element A reacts with water to form white fumes of HC*l*. Since HC*l* reacts with NaOH in a 1 : 1 ratio, 1 mole of chloride produces 3 moles of HC*l*.

$AlCl_3(s) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3HCl(g)$
$PCl_3(l) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HCl(aq)$

Element A can either belong to Group 13 or 15.

Answer: **B**

29 Compound N undergoes oxidative cleavage as below:



1: Correct. Both products are ketones.

2: Incorrect. There is no carboxylic acid formed.

3: Incorrect. There are two products (and both are organic).

Answer: **D**

30 **1**: Correct. Q is a ketone and will give orange precipitate with 2,4-DNPH, while no ppt will be formed with P.

2: Correct. Q is a primary alcohol and will turn $Cr_2O_7^{2-}$ from orange to green, while $Cr_2O_7^{2-}$ will remain orange with P. (Note that $Cr_2O_7^{2-}$ is not a strong enough oxidising agent to cause side chain oxidation to occur in P).

3: Correct. P is a carboxylic acid and will give effervescence which forms white precipitate with limewater, while no effervescence will be produced with Q.

Answer: **A**