**Y6 PRELIMINARY EXAMINATION 2021**
**CHEMISTRY HIGHER LEVEL**
**PAPER 2 MARKSCHEME**

**Discretionary QC penalty: -1 M for illegible handwriting, writing outside of the box, using correction tape/fluid and/or using non-blue or non-black ink pen.**

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 1. | a | | $MnO_2$ (s) + 4HCl (aq) → $Cl_2$ (g) + $2H_2O$ (l) + $MnCl_2$(aq) ✓ | *Ignore state symbols.* | 1 |
| 1. | b | | «2.67 g / 86.94 g mol -1 =» 0.0307 «mol» ✓ | *Accept ECF.* | 1 |
| 1. | c | | «$n_{HCl}$ = 2.00 mol $dm^{-3}$ × 0.2000 $dm^3$» = 0.400 mol ✓<br>«0.400 / 4 =»0.100 mol ***AND*** $MnO_2$ is the limiting reactant ✓ | *Accept other valid methods of determining the limiting reactant in M2.* | 2 |
| 1. | d | | «0.0307 mol × 4 = 0.123 mol»<br>«0.400 mol – 0.123 mol =» 0.277 «mol» ✓ | | 1 |
| 1. | e | | «0.0307 mol × 22.7 $dm^3$ $mol^{-1}$ =» 0.697 «$dm^3$» ✓ | *Accept methods employing pV = nRT.*<br>*ECF from 1(b).* | 1 |
| | | | | *Total* | 6 |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 2. | a | | <table><tr><th>Isotope</th><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr><tr><td>$^{74}Ge$</td><td>32</td><td>42</td><td>32</td></tr></table><br>all correct ✓ | | 1 |



| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 2. | b | | $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$ ✓ | | 1 |
| 2. | c | | «$2n^2$, where $n$ = 4», 32 ✓ | | 1 |
| 2. | d | | 5.7 × $10^{14}$ «$s^{-1}$/Hz» ✓ | | 1 |
| 2. | e | | 6.63 × $10^{-34}$ «J s» × 5.7 × $10^{14}$ «$s^{-1}$» ✓<br>= 3.78 × $10^{-19}$ J ✓ | *Award **[2]** for correct final answer.*<br>*ECF from 2(d).* | 2 |
| | | | | *Total* | 6 |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 3. | a | | colour change/from colourless or yellowish-green-to black/grey ✓ | *Accept "black solid/precipitate/ppt formed".* | 1 |
| 3. | b | | $Cl_2$ (aq)/(g) + $2e^- \rightarrow 2Cl^-$ (aq) ✓ | *Accept* 1/2 $Cl_2$ (aq)/(g) + $e^- \rightarrow Cl^-$ (aq)<br>*Ignore state symbols.* | 1 |
| 3. | c | | $At^+$, At, and $At^-$ ✓ | | 1 |
| 3. | d | i | d-d transitions/OWTTE ✓ | *Do **not** accept transitions between energy levels with no mention of d orbitals/sub-shells/sub-levels.* | 1 |
| 3. | d | ii | $[Cu(NH_3)_4(H_2O)_2]^{2+}$ (aq) is deep/dark blue or purple/violet ✓ | | 1 |
| 3. | d | iii | water (molecule)/aqua ligand/$H_2O$ ✓ | | 1 |
| 3. | d | iv | ligand replacement/ligand exchange/«ligand» substitution ✓ | *Do not accept "displacement".* | 1 |
| | | | | *Total* | 7 |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 4. | a | | $C_{28}$ ✓ | | 1 |
| 4. | b | | coolant/inert atmosphere/prevent oxidation/reaction/prevent combustion to $CO_2$, CO and $H_2O$ ✓ | *Do not accept "contamination".* | 1 |
| 4. | c | | $sp^2$ ✓<br><br>«and» $sp^3$ ✓ | | 2 |
| 4. | d | | sigma bonds are formed by end-on/axial overlap of orbitals ***AND*** pi bonds are formed by sideways overlap of orbitals ✓<br><br>sigma bonds are formed by overlap of $sp^2$ orbitals ***AND*** pi bonds are formed by overlap of «parallel» p orbitals ✓<br><br>sigma bonds have electron density between the two atoms/nuclei/along bond axis ***AND*** pi bonds have electron density above ***AND*** below internuclear/bond axis/σ bond ✓ | *Take note of command term 'compare'.* | 2 max |
| 4. | e | | $C_{60}$ is a non-polar molecule ***AND*** water is a polar molecule ✓<br><br>only weak London dispersion forces that cannot/replace strong hydrogen bonds in water ✓ | | 2 |
| 4. | f | | sublimation point increases with increasing molar mass ✓<br><br>«due to the» increase in the number of «polarizable» electrons available for formation of temporary dipoles/size or extent of electron cloud<br>***OR*** | | 2 |



| | | | | | |
|---|---|---|---|---|---|
| | | | «the extent of the» London dispersion forces attraction increases and hence the «thermal» energy required to separate the molecules increases ✓ | *Accept Van der Waals.* | |
| 4. | g | i. | [(500-450) / 450 × 100] = 11% ✓ | *Correct sign **not** needed for mark.*<br>*Do not accept 10%.* | 1 |
| 4. | g | ii. | systematic error ✓ | *Accept instrumental or calibration/zero error.* | 1 |
| | | | | *Total* | 12 |

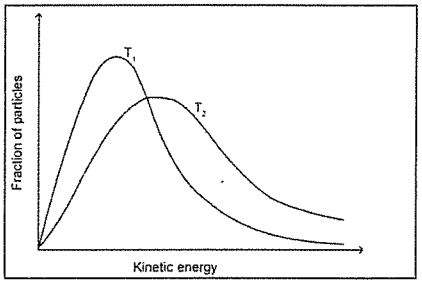
| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 5. | a | | *bonds broken*: 8(C–H) + 2(C–C) + 5(O=O) / 8 × 414 «kJ $mol^{-1}$» + 2 × 346 «kJ $mol^{-1}$» + 5 × 498 «kJ $mol^{-1}$» / 6494 «kJ» ✓<br><br>*bonds formed*: 6(C=O) + 8(O–H) / 6 × 804 «kJ $mol^{-1}$» + 8 × 463 «kJ $mol^{-1}$» / 8528 «kJ» ✓<br><br>«enthalpy change = bonds broken − bonds formed = 6494 kJ − 8528 kJ =» −2034 «kJ» ✓ | *Award **[3]** for correct final answer.* | 3 |
| 5. | b | | 4(−241.8 «kJ») ***AND*** 3(−393.5 «kJ») ***AND*** «1»(−105 «kJ») ✓<br><br>«$\Delta H^{\ominus}$ = 4(−241.8 «kJ») + 3(−393.5 «kJ») – «1»(−105 «kJ») =» −2043 «kJ» ✓ | *Award **[2]** for correct final answer.*<br>*Award **[1 max]** for −2219 «kJ».* | 2 |
| 5. | c | | $\Delta H^{\ominus}_f$ for any element = 0 «by definition»<br>***OR***<br>no energy required to form an element «in its stable form» from itself ✓ | | 1 |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 5. | d | | «bond enthalpies are» average values «over similar compounds»<br>***OR***<br>«bond enthalpies» are not specific to these compounds ✓ | *Accept reference to states (e.g. "change of states not accounted for", "not standard states", "not under standard conditions").* | 1 |
| 5. | e | | positive ***AND*** more moles «of gas» in products ✓ | *Take note of the state – gaseous state.* | 1 |
| 5. | f | | 4 × 188.8 «J $K^{-1}$» ***AND*** 3 × 213.8 «J $K^{-1}$» ***AND*** «1 ×» 270 «J $K^{-1}$» ***AND*** 5 × 205 «J $K^{-1}$» ✓<br><br>«$\Delta S^{\ominus}$ = 4(188.8 «J $K^{-1}$») + 3(213.8 «J $K^{-1}$») – [1(270 «J $K^{-1}$») + 5(205 «J $K^{-1}$»)] =» 102 «J $K^{-1}$» ✓ | *Award **[2]** for correct final answer.* | 2 |
| 5. | g | | «T = 5 + 273=» 278 K ✓<br><br>«S = 102 ÷ 1000» = 0.102 ✓<br><br>«$\Delta G^{\ominus}$ = −2043 − (278 × 0.102) =» −2071 «kJ» ✓ | *Award **[3]** for correct final answer.* | 3 |
| | | | | *Total* | 13 |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 6. | a | i | 2NO (g) + 2$H_2$ (g) → $N_2$ (g) + 2$H_2O$ (g) ✓ | | 1 |
| 6. | a | ii | rate = $k$ $[NO]^2$ $[H_2]$ ✓ | | 1 |
| 6. | a | iii | test the effect «on the reaction rate» of varying each concentration «independently» ✓<br><br>test the effect of varying [NO] «on rate», whilst keeping $[H_2]$ constant, rate proportional to $[NO]^2$<br>***AND*** | ***ECF** from a(ii).*<br><br>*M1 can be awarded implicitly in the description of the method.*<br><br>*If only one species in rate expression, M3 can be awarded for zero order discussion.* | 3 |



| | | | | | |
|---|---|---|---|---|---|
| | | | test effect of varying $[H_2]$ «on rate», whilst keeping [NO] constant, rate proportional to $[H_2]$ ✓<br><br>doubling [NO] quadruples rate<br>***AND***<br>doubling $[H_2]$ doubles rate ✓ | | |
| 6. | a | iv | no ***AND*** different mechanisms could give the same rate expression<br>***OR***<br>no ***AND*** mechanisms can only be disproved<br>***OR***<br>no ***AND*** just suggest it is consistent with the mechanism given<br>***OR***<br>no ***AND*** does not give information about what occurs after rate-determining step ✓ | | 1 |
| 6. | a | v | change of pressure «at constant volume and temperature» with time<br>***OR***<br>change of volume «at constant pressure and temperature» with time ✓ | *Accept other methods where rate can be monitored with time.* | 1 |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 6. | a | vi |  <br>correctly labelled axes ***AND*** starting at origin ✓<br>peak of $T_2$ curve lower ***AND*** to the right of $T_1$ curve ✓ | *Accept "probability «density» / number of particles / N / fraction" on y-axis.*<br>*Accept "kinetic E/KE/$E_K$" but not* just *"Energy/E" on x-axis.* | **2** |
| 6. | b | i | *Cl*2: first/1 ✓<br>*NO*: second/2 ✓ | | **2** |
| 6. | b | ii | 180 / 1.80 × $10^2$ «$dm^6$ $mol^{-2}$ $min^{-1}$» ✓ | | **1** |
| | | | | *Total* | **12** |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 7. | a | | «reaction quotient = $[SO_3]^2$ / ($[SO_2]^2$ × $[O_2]$)»<br>«$(0.600)^2$ / ($(0.250)^2$ × 0.400) =» 14.4 ✓<br><br>reaction quotient/*Q*/14.4/answer < $K_c$ / 280<br>***OR***<br>mixture needs more product for the number to equal $K_c$ ✓<br><br>reaction proceeds to the right/to products/forward direction ✓ | *M2 must be correct before M3 is awarded.* | **3** |



| | | | | | |
|---|---|---|---|---|---|
| 7. | b | | <table><tr><th></th><th>[CH3CHO] / mol dm−3</th><th>[CH3OH] / mol dm−3</th><th>[H+] / mol dm−3</th><th>[acetal] / mol dm−3</th><th>[H2O] / mol dm−3</th></tr><tr><td>Initial</td><td>0.20</td><td>0.10</td><td>0.05</td><td>0.00</td><td>0.00</td></tr><tr><td>Change ✓</td><td>**0.025**</td><td>**0.025**</td><td>**0/-**</td><td>**0.025**</td><td>**0.025**</td></tr><tr><td>Equilibrium ✓</td><td>**0.175**</td><td>**0.050**</td><td>**0.05**</td><td>0.025</td><td>**0.025**</td></tr></table> | *Ignore signs.*<br><br>*Table can be completed in terms of x.* | **2** |
| 7. | c | | $K_c$ = 1.4 ✓ | *Accept answer 1.43.* | **1** |
| 7. | d | | no effect/unchanged ✓ | | **1** |
| | | | | *Total* | **7** |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 8. | a | i | partially dissociates/ionizes «in water» ✓ | | **1** |
| 8. | a | ii | $ClO^-$ ✓ | | **1** |
| 8. | a | iii | «$[H^+] = 10^{-3.61}$ =» 2.5 × $10^{-4}$ «mol $dm^{-3}$» ✓ | | **1** |
| 8. | b | | *Any two of:*<br><br>«electrical» conductivity ***AND*** HCl greater ✓<br><br>pH ***AND*** citric acid higher ✓<br><br>titrate with strong base ***AND*** pH at equivalence higher for citric acid ✓ | *Accept "add universal indicator" **AND** "HCl more red/pink" for M2.*<br><br>*Accept any acid reaction **AND** HCl greater rise in temperature.*<br><br>*Accept specific examples throughout.*<br><br>*Do **not** accept "smell" or "taste".* | **2** |

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| | | | add reactive metal/carbonate/hydrogen carbonate ***AND*** stronger/more effervescence/faster reaction with HCl ✓<br><br>titration ***AND*** volume of alkali for complete neutralisation greater for citric acid ✓<br><br>titrate with strong base ***AND*** more than one equivalence point for complete neutralisation of citric acid ✓<br><br>titrate with strong base ***AND*** buffer zone with citric acid ✓ | | |
| **8.** | **c** | **i** | B: $CH_3COOH$ ***AND*** $CH_3COO^-$ ✓<br><br>C: $CH3COO^-$ ✓ | *Accept names.*<br>*Accept $CH_3COOK$ for $CH3COO^-$.* | **2** |
| **8.** | **c** | **ii** | phenolphthalein ✓ | *Accept "phenol red" or "bromothymol blue".* | **1** |
| **8.** | **c** | **iii** | B ***AND*** the region where small additions «of the base/KOH» result in little or no change in pH/resists change in pH<br>***OR***<br>B ***AND*** the flattest/very gradual region of the curve «at intermediate pH/before equivalence point»<br>***OR***<br>B ***AND*** half the volume needed to reach equivalence point<br>***OR***<br>B ***AND*** similar amounts of weak acid/$CH3COOH$/ethanoic acid ***AND*** conjugate base/$CH3COO^-$/ethanoate ✓ | | **1** |
| **8.** | **c** | **iv** | $K_a = [CH_3COO^-][H_3O^+] / [CH_3COOH]$ ✓ | *Accept $H^+$ instead of $H_3O^+$.* | **1** |



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| **8.** | **c** | **v** | «$K_a = 10^{-4.76} = 1.7 \times 10^{-5}$»<br>«$K_w = Ka \times Kb = 1.0 \times 10^{-14} = 1.7 \times 10^{-5} \times K_b$»<br>«$K_b$ =» $5.8 \times 10^{-10}$ ✓ | *Accept answers between 5.7–5.9 × $10^{-10}$.* | **1** |
| | | | | *Total* | **11** |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| **9.** | **a** | | Ni (s) + $I_2$ (aq) ⇌ $2I^-$ (aq) + $Ni^{2+}$ (aq) ✓ | *Accept other clear ways of indicating energy/ enthalpy changes.* | **1** |
| **9.** | **b** | | electron movement «in the wire» from Mn(s) to Ni(s) ✓<br><br>$E^\ominus$ «for reduction» of $Ni^{2+}$ is greater/less negative than $E^\ominus$ «for reduction» of $Mn^{2+}$<br>***OR***<br>$Ni^{2+}$ is a stronger oxidizing agent than $Mn^{2+}$<br>***OR***<br>Mn is a stronger reducing agent than Ni ✓ | | **2** |
| **9.** | **c** | | «0.54 V – (–1.18 V) = +»1.72 «V» ✓ | *Do **not** accept –1.72 V.* | **1** |
| **9.** | **d** | | Mn «(s)»/manganese ✓ | | **1** |
| **9.** | **e** | | *Positive electrode (anode):*<br>$2Cl^-$ (aq) ⇌ $Cl_2$ (g) + $2e^-$ ✓<br><br>$Cl^-$ oxidized/discharged because higher concentration<br>***OR***<br>electrode potential depends on concentration<br>***OR***<br>electrode potential values «of $H_2O$ and $Cl^-$» are close ✓ | | **4** |

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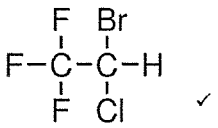
| | | | *Negative electrode (cathode):*<br><br>$2H_2O\ (l) + 2e^- \rightleftharpoons H_2\ (g) + 2OH^-\ (aq)$<br>***OR***<br>$2H^+\ (aq) + 2e^- \rightleftharpoons H_2\ (g)$ ✓<br><br>$H_2O/H^+$ reduced because $Na^+$ is a weaker oxidizing agent<br>***OR***<br>$Na^+$ not reduced to Na in water<br>***OR***<br>$H_2O/H^+$ easier to reduce than $Na^+$<br>***OR***<br>$H_2O/H^+$ more positive $E^\ominus$ «than $Na^+$»<br>***OR***<br>H lower in activity series/less reactive «than Na» ✓ | | |
| | | | | *Total* | **9** |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| **10.** | **a** | | «free» radical substitution ✓ | | **1** |
| **10.** | **b** | | UV light/ultra-violet light/ultra-violet radiation/sunlight ✓ | *Accept high temperature/150 to 500 °C.* | **1** |
| **10.** | **c** | | propagation «step» ✓ | | **1** |
| **10.** | **d** | | termination «step» ✓<br><br>$2CH_3CH_2CH_2\bullet \rightarrow C_6H_{14}$ ✓ | *$C_6H_{14}$ may be drawn out; penalize the absence of a dot – but it must be somewhere around the $CH_2$ terminal on the radical.* | **2** |



| | | | | | |
|---|---|---|---|---|---|
| **10.** | **e** | | $C_nH_{2n+2}$ ✓ | | **1** |
| **10.** | **f** | |  ✓ | | **1** |
| | | | | *Total* | **7** |

# Y6 PRELIMINARY EXAMINATION 2021
# CHEMISTRY HIGHER LEVEL
# PAPER 1 MARKSCHEME

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | C | 16. | D | 31. | B | 46. | – |
| 2. | B | 17. | A | 32. | A | 47. | – |
| 3. | D | 18. | D | 33. | B | 48. | – |
| 4. | A | 19. | B | 34. | C | 49. | – |
| 5. | C | 20. | A | 35. | B | 50. | – |
| 6. | C | 21. | C | 36. | A | 51. | – |
| 7. | C | 22. | D | 37. | C | 52. | – |
| 8. | C | 23. | B | 38. | D | 53. | – |
| 9. | C | 24. | D | 39. | B | 54. | – |
| 10. | C | 25. | A | 40. | D | 55. | – |
| 11. | B | 26. | B | 41. | – | 56. | – |
| 12. | B | 27. | D | 42. | – | 57. | – |
| 13. | A | 28. | A | 43. | – | 58. | – |
| 14. | A | 29. | D | 44. | – | 59. | – |
| 15. | D | 30. | A | 45. | – | 60. | – |