

Chem!stry

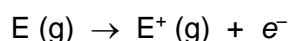
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Chemistry Olympiad Training for Secondary School Level – Part One

1. First ionization energy is the energy required to convert one mole of gaseous atoms into one mole of mono-positive gaseous ions. It is summarised by the equation below:



How does first ionization energy change across a Period (from left-to-right) and within a Group (from top-to-bottom) of the Periodic Table?

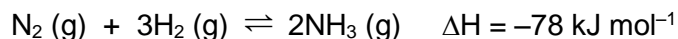
- A Increases across a Period and increases down a Group.
B Decreases across a Period and increases down a Group.
C Increases across a Period and Decreases down a Group.
D Decreases across a Period and Decreases down a Group.
2. The shapes of some molecules are shown below.

Tetrahedral	Pyramidal	Angular	Linear

Phosphine is a compound of phosphorus and hydrogen. What shape is a phosphine molecule likely to have?

- A Angular
B Linear
C Pyramidal
D Tetrahedral

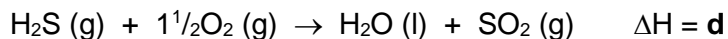
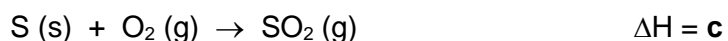
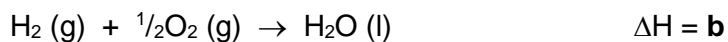
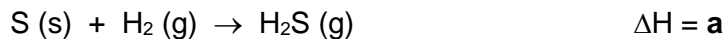
3. Nitrogen and hydrogen react according to the equation:



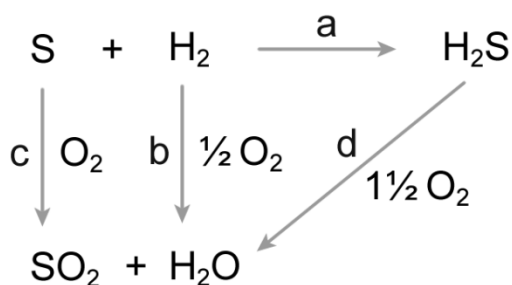
According to Le Chatelier's principle, which change in temperature and pressure will increase the yield of ammonia?

- A Increase temperature and increase pressure.
 - B Increase temperature and decrease pressure.
 - C Decrease temperature and increase pressure.
 - D Decrease temperature and decrease pressure.
4. Which one of the following is a *disproportionation* reaction?
- A $\text{Zn} + \text{CuSO}_4 \rightarrow \text{ZnSO}_4 + \text{Cu}$
 - B $2\text{CO} \rightarrow \text{C} + \text{CO}_2$
 - C $4\text{S} + 5\text{O}_2 \rightarrow 2\text{SO}_2 + 2\text{SO}_3$
 - D $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + 2\text{H}_2\text{O} + \text{Cl}_2$
5. Which of the following compounds contains ions which are *isoelectric*?
- A CaO
 - B CaBr₂
 - C Na₂O
 - D LiF
6. Which one of the following reactions has a value for $\Delta S^\circ > 0$?
- A $\text{S}_8 (\text{l}) \rightarrow \text{S}_8 (\text{s})$
 - B $\text{H}_2 (\text{g}) + \text{O}_2 (\text{g}) \rightarrow \text{H}_2\text{O}_2 (\text{l})$
 - C $\text{H}_2 (\text{g}) + 2\text{Ag}^+ (\text{aq}) \rightarrow 2\text{H}^+ (\text{aq}) + 2\text{Ag} (\text{s})$
 - D $\text{PCl}_5 (\text{g}) \rightarrow \text{PCl}_3 (\text{g}) + \text{Cl}_2 (\text{g})$

7. Study the following reactions:



The relationships between the four reactions, and their enthalpy changes, are summarised in the diagram below:



What is the relationship between **a**, **b**, **c** and **d**?

A $a = b + c - d$

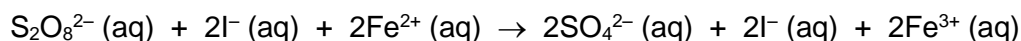
B $a = d - b - c$

C $a = b - c - d$

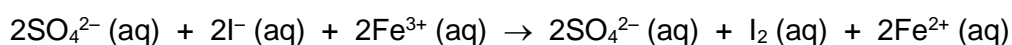
D $a = d + c - b$

8. A reaction takes place in two stages:

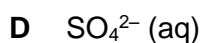
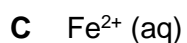
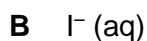
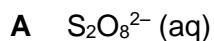
Stage 1:



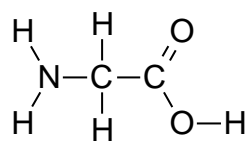
Stage 2:



Which ion is the **catalyst** in this reaction?



9. Some of the covalent bonds in an amino acid molecule are *polar*. A polar covalent bond arises when a bonding pair of electrons is not shared evenly between two atoms.



The table contains information about the attraction of some atoms for bonded pairs of electrons.

Atom	Relative Attraction for a Bonding Pair of Electrons
H	2.2
C	2.5
N	3.0
O	3.5

Based on this information, the most polar covalent bond in the amino acid will be:

- A** C – H **B** N – H
C C – O **D** O – H

10. The electronic configuration for an atom of nitrogen (atomic number = 7) is given below:

1s	2s	2p	3s
↑↓	↑↓	↑ ↑ ↑	

Which one of the following is the correct electronic configuration for a sodium ion?

- A**

1s	2s	2p	3s
↑↓	↑↓	↑↓ ↑↓ ↑	

B

1s	2s	2p	3s
↑↓	↑↓	↑↓ ↑↓ ↑↓	

C

1s	2s	2p	3s
↑↓	↑↓	↑↓ ↑↓ ↑↓	↑

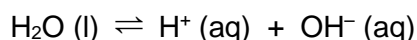
D

1s	2s	2p	3s
↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓

15. Which statement about bonding is correct?

- A A σ bond has cylindrical symmetry about the bonding axis.
- B A π bond is twice as strong as a σ bond.
- C A double bond consists of two π bonds.
- D A π bond results from the sideways overlap of hybridised orbitals.

16. Water spontaneously ionises according to the following chemical equation:



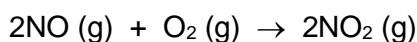
The pH of an aqueous solution can be calculated using the following equation:

$$\text{pH} = -\log_{10}[\text{H}^+]$$

What is the pH of an aqueous solution that contains $0.0100 \text{ mol dm}^{-3}$ NaOH?

- A 1×10^{-7}
- B 7
- C 12
- D 14

17. Consider the gas-phase reaction between nitrogen monoxide and oxygen showing the initial concentrations of the reactants at a constant temperature:

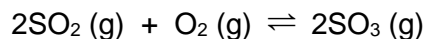


Experiment	[NO] / mol dm^{-3}	[O ₂] / mol dm^{-3}	Initial Rate of NO ₂ Formation / $\text{mol dm}^{-3} \text{ s}^{-1}$
1	0.020	0.020	0.057
2	0.040	0.040	0.455
3	0.040	0.020	0.228

What is the order of the reaction with respect to NO (g) and O₂ (g)?

- A NO (g) = zero order O₂ (g) = third order
- B NO (g) = first order O₂ (g) = second order
- C NO (g) = second order O₂ (g) = first order
- D NO (g) = third order O₂ (g) = zero order

18. During the manufacture of sulfuric acid, sulfur(IV) oxide reacts with oxygen to form sulfur(VI) oxide. The balanced chemical equation for this reaction, known as the *Contact Process*, is shown below:



What is the equilibrium constant for this reaction?

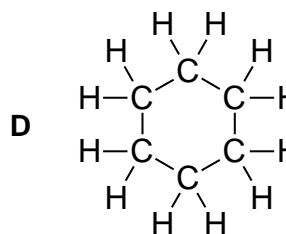
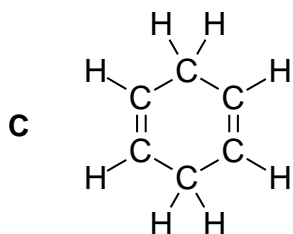
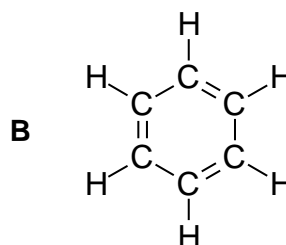
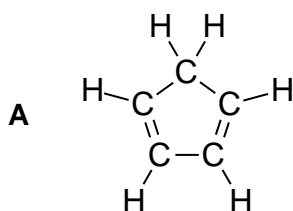
A $K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 \times [\text{O}_2]}$

B $K_c = \frac{[\text{SO}_2]^2 \times [\text{O}_2]}{[\text{SO}_3]^2}$

C $K_c = \frac{2[\text{SO}_3]}{2[\text{SO}_2] \times [\text{O}_2]}$

D $K_c = \frac{2[\text{SO}_2] \times [\text{O}_2]}{2[\text{SO}_3]}$

19. Which one of the following organic compounds is *aromatic*?



20. Given the enthalpy changes:



What is ΔH for the reaction **2A + B + D → 2F** ?

- A** 0 kJ mol^{-1}
B -30 kJ mol^{-1}
C -40 kJ mol^{-1}
D -70 kJ mol^{-1}

The Periodic Table of the Elements

Group																	
I	II											III	IV	V	VI	VII	0
		<div>1 H hydrogen 1</div>															
<div>7 Li lithium 3</div>	<div>9 Be beryllium 4</div>											<div>11 B boron 5</div>	<div>12 C carbon 6</div>	<div>14 N nitrogen 7</div>	<div>16 O oxygen 8</div>	<div>19 F fluorine 9</div>	<div>20 Ne neon 10</div>
<div>23 Na sodium 11</div>	<div>24 Mg magnesium 12</div>											<div>27 Al aluminium 13</div>	<div>28 Si silicon 14</div>	<div>31 P phosphorus 15</div>	<div>32 S sulfur 16</div>	<div>35.5 Cl chlorine 17</div>	<div>40 Ar argon 18</div>
<div>39 K potassium 19</div>	<div>40 Ca calcium 20</div>	<div>45 Sc scandium 21</div>	<div>48 Ti titanium 22</div>	<div>51 V vanadium 23</div>	<div>52 Cr chromium 24</div>	<div>55 Mn manganese 25</div>	<div>56 Fe iron 26</div>	<div>59 Co cobalt 27</div>	<div>59 Ni nickel 28</div>	<div>64 Cu copper 29</div>	<div>65 Zn zinc 30</div>	<div>70 Ga gallium 31</div>	<div>73 Ge germanium 32</div>	<div>75 As arsenic 33</div>	<div>79 Se selenium 34</div>	<div>80 Br bromine 35</div>	<div>84 Kr krypton 36</div>
<div>85 Rb rubidium 37</div>	<div>88 Sr strontium 38</div>	<div>89 Y yttrium 39</div>	<div>91 Zr zirconium 40</div>	<div>93 Nb niobium 41</div>	<div>96 Mo molybdenum 42</div>	<div>101 Ru ruthenium 44</div>	<div>103 Rh rhodium 45</div>	<div>106 Pd palladium 46</div>	<div>108 Ag silver 47</div>	<div>112 Cd cadmium 48</div>	<div>115 In indium 49</div>	<div>119 Sn tin 50</div>	<div>122 Sb antimony 51</div>	<div>127 I iodine 53</div>	<div>128 Te tellurium 52</div>	<div>131 Xe xenon 54</div>	
<div>133 Cs caesium 55</div>	<div>137 Ba barium 56</div>	<div>139 La lanthanum 57</div>	<div>178 Hf hafnium 72</div>	<div>181 Ta tantalum 73</div>	<div>184 W tungsten 74</div>	<div>186 Re rhenium 75</div>	<div>190 Os osmium 76</div>	<div>192 Ir iridium 77</div>	<div>195 Pt platinum 78</div>	<div>197 Au gold 79</div>	<div>201 Hg mercury 80</div>	<div>204 Tl thallium 81</div>	<div>207 Pb lead 82</div>	<div>209 Bi bismuth 83</div>	<div>210 Po polonium 84</div>	<div>210 At astatine 85</div>	<div>222 Rn radon 86</div>
<div>87 Fr francium</div>	<div>88 Ra radium</div>	<div>89 Ac actinium</div>															

*58-71 Lanthanoid series

+90-103 Actinoid series

<div>140 Ce cerium 58</div>	<div>141 Pr praseodymium 59</div>	<div>144 Nd neodymium 60</div>	<div>150 Sm samarium 62</div>	<div>152 Eu europium 63</div>	<div>157 Gd gadolinium 64</div>	<div>159 Tb terbium 65</div>	<div>162 Dy dysprosium 66</div>	<div>165 Ho holmium 67</div>	<div>167 Er erbium 68</div>	<div>169 Tm thulium 69</div>	<div>173 Yb ytterbium 70</div>	<div>175 Lu lutetium 71</div>
<div>232 Th thorium 90</div>	<div>238 Pa protactinium 91</div>	<div>238 U uranium 92</div>	<div>238 Pu plutonium 94</div>	<div>238 Am americium 95</div>	<div>238 Cm curium 96</div>	<div>238 Bk berkelium 97</div>	<div>238 Cf californium 98</div>	<div>238 Es einsteinium 99</div>	<div>238 Fm fermium 100</div>	<div>238 Md mendelevium 101</div>	<div>238 No nobelium 102</div>	<div>238 Lr lawrencium 103</div>

Key

a

X

b

a = relative atomic mass

X = atomic symbol

b = proton (atomic) number

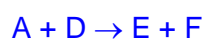
Answers

1. C
2. C
3. C
4. B
5. C
6. D
7. A
8. C
9. D
10. B
11. C
12. B
13. C
14. C
15. A
16. C
17. C
18. A
19. B
20. B

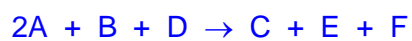
if...



and...



then...

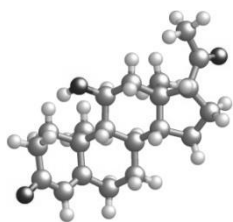


$$\Delta H = (-35 \text{ for } A + B) + (+20 \text{ for } A + D) = \underline{-15 \text{ kJ}}$$

C + E can react to form the second molecule of F



$$\text{overall enthalpy change} = (-15) + (-15) = \underline{-30 \text{ kJ}}$$



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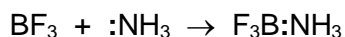
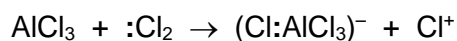
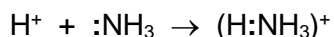
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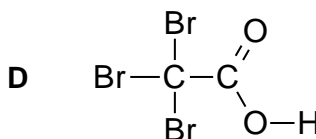
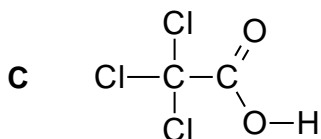
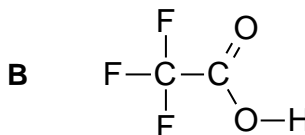
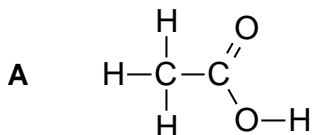
Chemistry Olympiad Training for Secondary School Level – Part Two

1. Study the three chemical reactions shown below:



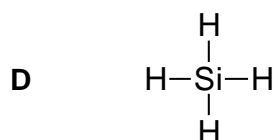
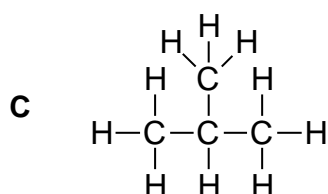
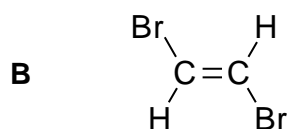
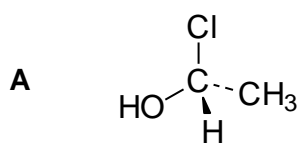
What do all three reactions have in common?

- A They are all precipitation reactions.
 - B They are all redox reactions.
 - C They are reactions of Lewis acids and bases.
 - D They are reactions of Brønsted-Lowry acids and bases.
2. Which one of the four carboxylic acids shown below is the strongest acid?

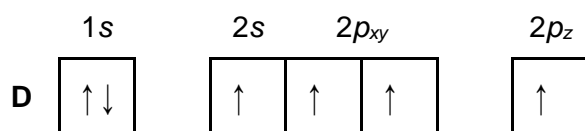
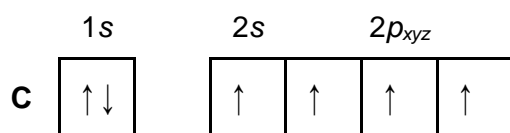
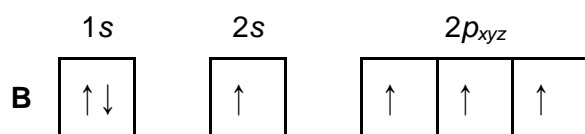
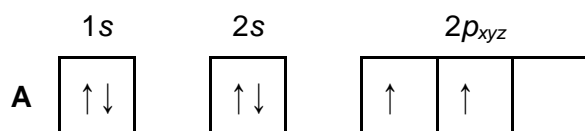


3. The enthalpy change, under standard conditions, for which one of the reactions below would be equal to the ΔH_f° of NaOH (s)?
- A $\text{Na(s)} + \text{H}_2\text{O(l)} \rightarrow \text{NaOH(s)} + \frac{1}{2}\text{H}_2\text{(g)}$
 - B $\text{Na(s)} + \frac{1}{2}\text{O}_2\text{(g)} + \frac{1}{2}\text{H}_2\text{(g)} \rightarrow \text{NaOH(s)}$
 - C $\text{Na(s)} + \frac{1}{2}\text{H}_2\text{O}_2\text{(l)} \rightarrow \text{NaOH(s)}$
 - D $\text{Na}^+\text{(aq)} + \text{OH}^-\text{(aq)} \rightarrow \text{NaOH(s)}$

4. Which one of the following organic compounds will rotate plane polarised light?



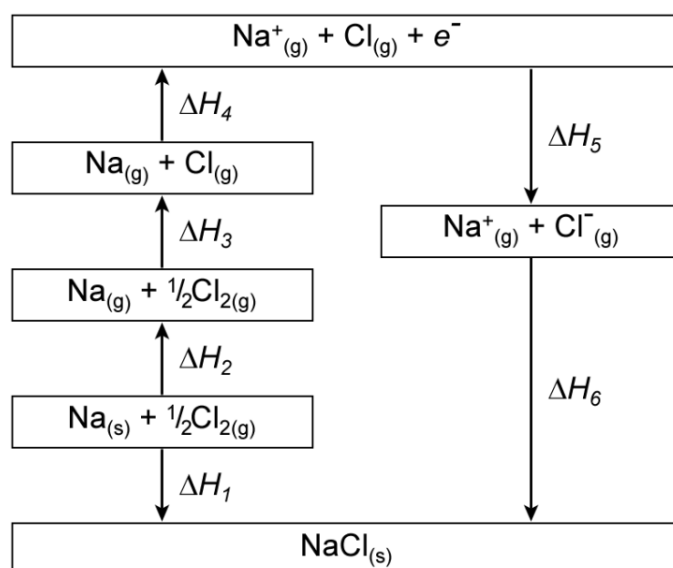
5. Which one of the following electronic arrangements shows sp^3 hybridisation in carbon?



6. Which calcium compound is not appreciably more soluble in 0.1 mol dm⁻³ hydrochloric acid than it is in pure water?

- A** Limestone, CaCO₃
- B** Slaked lime, Ca(OH)₂
- C** Gypsum, CaSO₄·2H₂O
- D** Hydroxyapatite, Ca₅(OH)(PO₄)₃

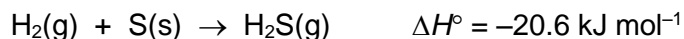
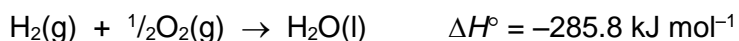
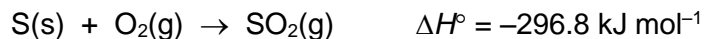
7. The Born-Haber cycle shown below represents the formation of sodium chloride from sodium and chlorine:



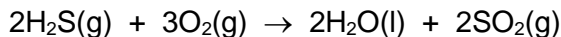
Which of the enthalpy changes (ΔH) is correctly paired with its description?

- A ΔH_1 is the enthalpy change of combustion for sodium chloride.
 - B ΔH_4 is the first electron affinity for sodium.
 - C ΔH_5 is the first ionisation energy for chlorine.
 - D ΔH_6 is the lattice enthalpy for sodium chloride.
8. At the molecular level, the factor that determines whether a substance will be a solid, liquid or gas is the balance between the...
- A Kinetic energies of the molecules and their intermolecular forces.
 - B Potential energies of the molecules and their intermolecular forces.
 - C Kinetic energies of the molecules and their intramolecular forces.
 - D Potential energies of the molecules and their intramolecular forces.
9. What is the oxidation state of C in methanal, CH_2O ?
- A -2
 - B 0
 - C +2
 - D +4
10. Which molecule is correctly matched with its shape as predicted by as predicted by valence shell electron pair repulsion theory (VSEPR)?
- A CH_4 octahedral
 - B NH_3 linear
 - C PCl_5 trigonal bipyramidal
 - D SF_6 tetrahedral

15. Given chemical equations for these reactions:



What is the value of ΔH for the reaction given below?



A $-603.2 \text{ kJ mol}^{-1}$

B $-562.0 \text{ kJ mol}^{-1}$

C $-1206.4 \text{ kJ mol}^{-1}$

D $-1124.0 \text{ kJ mol}^{-1}$

16. What property of the oxygen atom is represented by the equation $\text{O(g)} + \text{e}^- \rightarrow \text{O}^-\text{(g)}$?

A Electronegativity.

B First electron affinity.

C First ionisation energy.

D Lattice energy.

17. Which one of the following isoelectronic species has the largest atomic radius?

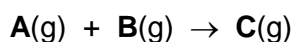
A K^+

B Ca^{2+}

C P^{3-}

D S^{2-}

18. Chemical **A** reacts with chemical **B** to form chemical **C** according to the reaction given below:



The data below was obtained for the reaction between **A** and **B**. What is the rate equation for this reaction?

Experiment	[A] / mol dm ⁻³	[B] / mol dm ⁻³	Initial Rate of Reaction / mol dm ⁻³ s ⁻¹
1	0.10	0.10	6.5×10^{-5}
2	0.20	0.10	2.6×10^{-4}
3	0.10	0.20	6.5×10^{-5}

A Rate = $k \times [\text{A}]$

B Rate = $k \times [\text{A}] \times [\text{B}]$

C Rate = $k \times [\text{A}]^2$

D Rate = $k \times [\text{A}]^2 \times [\text{B}]$

19. Values for some standard electrode potentials (E°) are given in the table below:

Half-reaction	E° / V
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	-0.760
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.744
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.409

Use the E° values in the table to determine which one of the following reactions will give the highest potential difference in a simple voltaic cell.

- A $3\text{Zn}^{2+}(\text{aq}) + 2\text{Cr}(\text{s}) \rightarrow 3\text{Zn}(\text{s}) + 2\text{Cr}^{3+}(\text{aq})$
- B $3\text{Zn}(\text{s}) + 2\text{Cr}^{3+}(\text{aq}) \rightarrow 3\text{Zn}^{2+}(\text{aq}) + 2\text{Cr}(\text{s})$
- C $\text{Zn}^{2+}(\text{aq}) + \text{Fe}(\text{s}) \rightarrow \text{Zn}(\text{s}) + \text{Fe}^{2+}(\text{aq})$
- D $\text{Zn}(\text{s}) + \text{Fe}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Fe}(\text{s})$

20. The ideal gas equation is given below:

$$PV = nRT$$

$$R = \text{gas constant} = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$n = \text{amount of gas / mol}$$

What volume does 64.0 g of oxygen gas occupy at a pressure of 101 000 pa and a temperature of 100 °C?

Note: $A_r[\text{O}] = 16.0$

- A 0.0165 m³
- B 0.0614 m³
- C 0.123 m³
- D 0.0329 m³

The Periodic Table of the Elements

Group																	
I	II						III	IV	V	VI	VII	0					
<div>1 H hydrogen 1</div>												<div>4 He helium 2</div>					
<div>7 Li lithium 3</div>	<div>9 Be beryllium 4</div>						<div>11 B boron 5</div>	<div>12 C carbon 6</div>	<div>14 N nitrogen 7</div>	<div>16 O oxygen 8</div>	<div>19 F fluorine 9</div>	<div>20 Ne neon 10</div>					
<div>23 Na sodium 11</div>	<div>24 Mg magnesium 12</div>						<div>27 Al aluminium 13</div>	<div>28 Si silicon 14</div>	<div>31 P phosphorus 15</div>	<div>32 S sulfur 16</div>	<div>35.5 Cl chlorine 17</div>	<div>40 Ar argon 18</div>					
<div>39 K potassium 19</div>	<div>40 Ca calcium 20</div>	<div>45 Sc scandium 21</div>	<div>48 Ti titanium 22</div>	<div>51 V vanadium 23</div>	<div>52 Cr chromium 24</div>	<div>55 Mn manganese 25</div>	<div>56 Fe iron 26</div>	<div>59 Co cobalt 27</div>	<div>59 Ni nickel 28</div>	<div>64 Cu copper 29</div>	<div>65 Zn zinc 30</div>	<div>70 Ga gallium 31</div>	<div>73 Ge germanium 32</div>	<div>75 As arsenic 33</div>	<div>79 Se selenium 34</div>	<div>80 Br bromine 35</div>	<div>84 Kr krypton 36</div>
<div>85 Rb rubidium 37</div>	<div>88 Sr strontium 38</div>	<div>89 Y yttrium 39</div>	<div>91 Zr zirconium 40</div>	<div>93 Nb niobium 41</div>	<div>96 Mo molybdenum 42</div>	<div>101 Ru ruthenium 44</div>	<div>103 Rh rhodium 45</div>	<div>106 Pd palladium 46</div>	<div>108 Ag silver 47</div>	<div>112 Cd cadmium 48</div>	<div>115 In indium 49</div>	<div>119 Sn tin 50</div>	<div>122 Sb antimony 51</div>	<div>127 Te tellurium 52</div>	<div>127 I iodine 53</div>	<div>131 Xe xenon 54</div>	
<div>133 Cs caesium 55</div>	<div>137 Ba barium 56</div>	<div>139 La lanthanum 57</div>	<div>178 Hf hafnium 72</div>	<div>181 Ta tantalum 73</div>	<div>184 W tungsten 74</div>	<div>186 Re rhenium 75</div>	<div>190 Os osmium 76</div>	<div>192 Ir iridium 77</div>	<div>195 Pt platinum 78</div>	<div>197 Au gold 79</div>	<div>201 Hg mercury 80</div>	<div>204 Tl thallium 81</div>	<div>207 Pb lead 82</div>	<div>209 Bi bismuth 83</div>	<div>– Po polonium 84</div>	<div>– At astatine 85</div>	<div>– Rn radon 86</div>
<div>– Fr francium 87</div>	<div>– Ra radium 88</div>	<div>– Ac actinium 89</div>															
*58-71 Lanthanoid series																	
†90-103 Actinoid series																	

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	162 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71	
232 Th thorium 90	– Pa protactinium 91	238 U uranium 92	– Np neptunium 93	– Pu plutonium 94	– Am americium 95	– Cm curium 96	– Bk berkelium 97	– Cf californium 98	– Es einsteinium 99	– Fm fermium 100	– Md mendelevium 101	– No nobelium 102	– Lr lawrencium 103

Key

a

X

b

a = relative atomic mass

X = atomic symbol

b = proton (atomic) number

Key

a

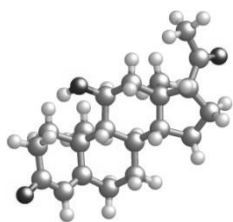
X

b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

Answers

1. D
2. B
3. B
4. A
5. C
6. C
7. D
8. A
9. B
10. C
11. B
12. C
13. D
14. B
15. D
16. B
17. C
18. C
19. D
20. B



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Chemistry Olympiad Training for Secondary School Level – Part Three

- Which one of the following substances has the highest melting point?

A Li_2O	B MgO
C CO_2	D N_2O_5
- Which one of the following nitrogen halides is least stable thermodynamically?

A NF_3	B NCl_3
C NBr_3	D NI_3
- Which one of the following organic compounds is least soluble in water?

A Butan-1-ol	B Ethanol
C Methanol	D Propan-1-ol
- Use the information provided to calculate the standard enthalpy change of formation for ethyne, $\text{C}_2\text{H}_2(\text{g})$, in kJ mol^{-1} .

$\text{C}_2\text{H}_2(\text{g}) + \frac{5}{2}\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$	$\Delta H^\circ = -1299.5$
$\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$	$\Delta H^\circ = -393.5$
$\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$	$\Delta H^\circ = -285.8$

A -1978.8	B -1121.4
C $+226.7$	D $+453.4$
- For a reaction at constant pressure to be spontaneous, which one of the following relationships must be correct?

A $\Delta H_{\text{rxn}} < 0$	B $\Delta G_{\text{rxn}} < 0$
C $\Delta S_{\text{rxn}} < 0$	D $\Delta S_{\text{univ}} < 0$

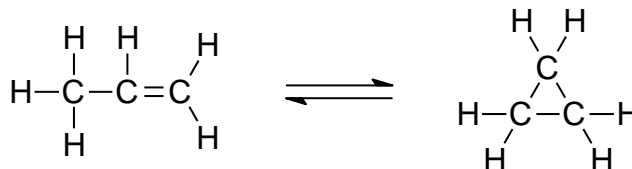
6. In order to calculate the lattice energy of NaCl using a Born-Haber cycle, which value is not needed?
- A The enthalpy of sublimation of Na(s).
 B The first ionisation energy of Cl(g).
 C The bond dissociation energy of Cl₂(g).
 D The enthalpy of formation of NaCl(s).

7. Initial rate data for the reaction $X + Y \rightarrow Z$ is given in the table below:

[X] / mol dm ⁻³	[Y] / mol dm ⁻³	Rate / mol dm ⁻³ s ⁻¹
0.10	0.10	0.020
0.10	0.20	0.080
0.30	0.30	0.540

What is the rate law for this reaction?

- A rate = $k[X]^2$ B rate = $k[Y]^2$
 C rate = $k[X][Y]$ D rate = $k[X][Y]^2$
8. The gas phase reaction shown below is endothermic as written:



Which change(s) will increase the quantity of CH₃CH=CH₂ at equilibrium?

- I Increasing the temperature.
 II Increasing the pressure.
- A I only. B II only.
 C Both I and II. D Neither I nor II.
9. Which ion is not isoelectric with argon?
- A S²⁻ B K⁺
 C Sc²⁺ D Ti⁴⁺
10. Which substance will form hydrogen bonds to water molecules but will not form hydrogen bonds with its own molecules?
- A HF B C₂H₅OH
 C CH₃NH₂ D CH₃OCH₃

11. What is the number of π -bonds in butenedioic acid, $\text{C}_4\text{H}_4\text{O}_4$?

A 1

B 2

C 3

D 4

12. In which list are the ions arranged in order of increasing size?

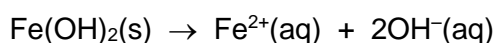
A $F^- < S^{2-} < Al^{3+} < Mg^{2+}$

B $F^- < S^{2-} < Mg^{2+} < Al^{3+}$

C $\text{Mg}^{2+} < \text{F}^- < \text{Al}^{3+} < \text{S}^{2-}$

D $\text{Al}^{3+} < \text{Mg}^{2+} < \text{F}^- < \text{S}^{2-}$

13. The pH of a saturated solution of $\text{Fe}(\text{OH})_2$ is 8.67. What is the K_{sp} for $\text{Fe}(\text{OH})_2$?



$$K_{sp} = [\text{Fe}^{2+}(\text{aq})] \times [\text{OH}^{-}(\text{aq})]^2$$

A 5×10^{-6}

B 2×10^{-11}

C 1×10^{-16}

D 5×10^{-17}

14. Molecules of which type(s) do not contain a C=O bond?

I Amide

II Amine

III Ether

IV Ester

A II only.

B I and IV only.

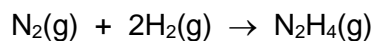
C II and III only.

D III and IV only.

15. Bond energies for hydrogen and nitrogen are given in the table below:

Bond Energies / kJ mol ⁻¹	
N≡N	946
N=N	418
N–N	163
N–H	389
H–H	436

What is the ΔH_f° for $\text{N}_2\text{H}_4(\text{g})$ in kJ mol^{-1} ?



A +156

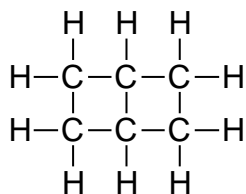
B +99

C -99

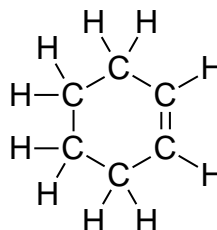
D -156

16. Which isomer of C_6H_{10} is least stable?

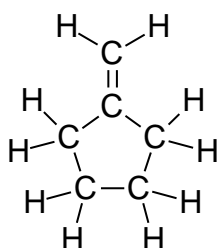
A



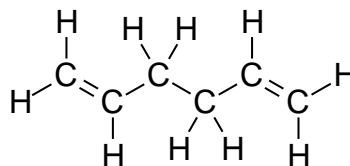
B



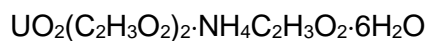
C



D



17. The formula for a compound of uranium is given below:



The relative molecular mass of this compound is 573. What is the percentage, by mass, of oxygen in this compound?

A 5.58%

B 16.8%

C 22.3%

D 39.1%

18. The percentage composition of the high explosive HNS is given in the table below:

C	H	N	O
37.35%	1.34%	18.67%	42.65%

The relative molecular mass of HNS is 450.22. What is the molecular formula of HNS?

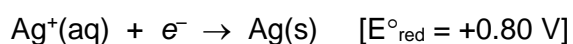
A $C_{13}H_4N_7O_{12}$

B $C_{14}H_6N_6O_{12}$

B $C_{15}H_{10}N_6O_{11}$

C $C_{16}H_{12}N_5O_{11}$

19. In an operating voltaic cell, electrons move through the external circuit and ions move through the electrolyte solution. Which one of the following statements correctly describes these movements?
- A Electrons and negative ions both move towards the anode.
 - B Electrons and negative ions both move towards the cathode.
 - C Electrons move towards the anode and negative ions move towards the cathode.
 - D Electrons move towards the cathode and negative ions move towards the anode.
20. An unknown metal, M(s) and its aqueous salt, $M(\text{NO}_3)_2(\text{aq})$ are combined with a silver half-cell in which the following reaction takes place:



If $E^\circ_{\text{cell}} = +1.36 \text{ V}$, what is E°_{red} for $M^{2+}(\text{aq}) + 2e^- \rightarrow M(\text{s})$?

- | | |
|-----------|-----------|
| A +0.56 V | B +0.24 V |
| C -0.24 V | D -0.56 V |

The Periodic Table of the Elements

Group																	
I	II						III	IV	V	VI	VII	0					
<div>1 H hydrogen 1</div>												<div>4 He helium 2</div>					
<div>7 Li lithium 3</div>	<div>9 Be beryllium 4</div>						<div>11 B boron 5</div>	<div>12 C carbon 6</div>	<div>14 N nitrogen 7</div>	<div>16 O oxygen 8</div>	<div>19 F fluorine 9</div>	<div>20 Ne neon 10</div>					
<div>23 Na sodium 11</div>	<div>24 Mg magnesium 12</div>						<div>27 Al aluminium 13</div>	<div>28 Si silicon 14</div>	<div>31 P phosphorus 15</div>	<div>32 S sulfur 16</div>	<div>35.5 Cl chlorine 17</div>	<div>40 Ar argon 18</div>					
<div>39 K potassium 19</div>	<div>40 Ca calcium 20</div>	<div>45 Sc scandium 21</div>	<div>48 Ti titanium 22</div>	<div>51 V vanadium 23</div>	<div>52 Cr chromium 24</div>	<div>55 Mn manganese 25</div>	<div>56 Fe iron 26</div>	<div>59 Co cobalt 27</div>	<div>59 Ni nickel 28</div>	<div>64 Cu copper 29</div>	<div>65 Zn zinc 30</div>	<div>70 Ga gallium 31</div>	<div>73 Ge germanium 32</div>	<div>75 As arsenic 33</div>	<div>79 Se selenium 34</div>	<div>80 Br bromine 35</div>	<div>84 Kr krypton 36</div>
<div>85 Rb rubidium 37</div>	<div>88 Sr strontium 38</div>	<div>89 Y yttrium 39</div>	<div>91 Zr zirconium 40</div>	<div>93 Nb niobium 41</div>	<div>96 Mo molybdenum 42</div>	<div>101 Ru ruthenium 44</div>	<div>103 Rh rhodium 45</div>	<div>106 Pd palladium 46</div>	<div>108 Ag silver 47</div>	<div>112 Cd cadmium 48</div>	<div>115 In indium 49</div>	<div>119 Sn tin 50</div>	<div>122 Sb antimony 51</div>	<div>127 Te tellurium 52</div>	<div>127 I iodine 53</div>	<div>131 Xe xenon 54</div>	
<div>133 Cs caesium 55</div>	<div>137 Ba barium 56</div>	<div>139 La lanthanum 57</div>	<div>178 Hf hafnium 72</div>	<div>181 Ta tantalum 73</div>	<div>184 W tungsten 74</div>	<div>186 Re rhenium 75</div>	<div>190 Os osmium 76</div>	<div>192 Ir iridium 77</div>	<div>195 Pt platinum 78</div>	<div>197 Au gold 79</div>	<div>201 Hg mercury 80</div>	<div>204 Tl thallium 81</div>	<div>207 Pb lead 82</div>	<div>209 Bi bismuth 83</div>	<div>– Po polonium 84</div>	<div>– At astatine 85</div>	<div>– Rn radon 86</div>
<div>– Fr francium 87</div>	<div>– Ra radium 88</div>	<div>– Ac actinium 89</div>															
*58-71 Lanthanoid series																	
†90-103 Actinoid series																	

Key

a

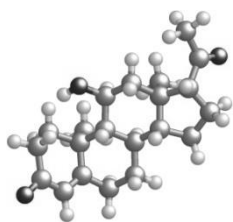
X

b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

Answers

1. B
2. D
3. A
4. C
5. B
6. B
7. D
8. D
9. C
10. D
11. C
12. D
13. D
14. C
15. B
16. A
17. D
18. B
19. D
20. D



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Chemistry Olympiad Training for Secondary School Level – Part Four

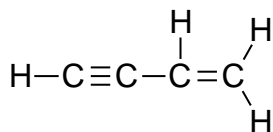
1. The K_a value of an acid is given by the equation:

$$K_a = \frac{[H^+] \times [A^-]}{[HA]}$$

Which one of the following acids is the strongest acid?

- | | | | |
|----------|-------------------|-------------|------------------------------|
| A | Oxalic acid | $H_2C_2O_4$ | $K_a = 5.90 \times 10^{-2}$ |
| B | Hydrofluoric acid | HF | $K_a = 7.20 \times 10^{-4}$ |
| C | Ethanoic acid | CH_3COOH | $K_a = 1.76 \times 10^{-5}$ |
| D | Phenol | C_6H_5OH | $K_a = 1.60 \times 10^{-10}$ |

2. The structural formula of but-3-yn-1-ene is given below:



How many π -bonding electrons are there in a single molecule of but-3-yn-1-ene?

- | | |
|-------------|-------------|
| A 3 | B 6 |
| C 10 | D 20 |
3. Phenolphthalein is a common indicator that is used for acid-base titrations. Phenolphthalein's percentage composition by mass is given below:

C = 75.46 %

H = 4.43 %

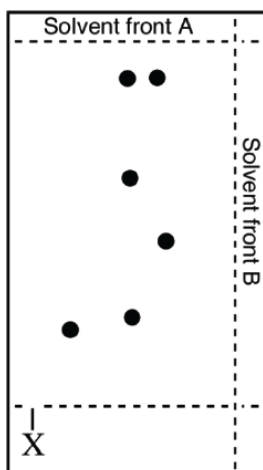
O = 20.11 %

What is the empirical formula of phenolphthalein?

- | | |
|-------------------------|-------------------------|
| A $C_7H_3O_2$ | B $C_{10}H_7O_2$ |
| C $C_{15}H_4O_2$ | D $C_5H_2O_3$ |

8. Thin layer chromatography (TLC) is used to separate mixtures of compounds based upon the different polarities of the compounds. This is done based on their interactions with the polar stationary phase and the less polar mobile phase.

A mixture of compounds is placed on the TLC plate at the position marked "X". Through capillary attraction, solvent **A** moves up the plate until it reaches the point shown. The plate is then dried, rotated 90° and the process repeated using solvent **B** to give the following result:

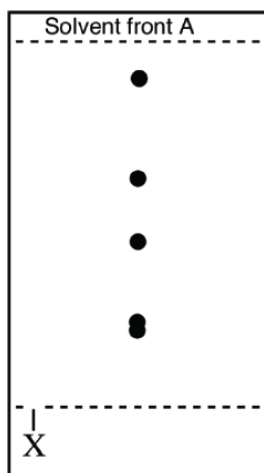


Which of the following plates would be the one that you would expect to obtain after using **only** solvent **A** as the mobile phase?

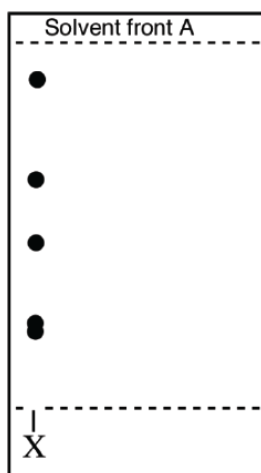
A



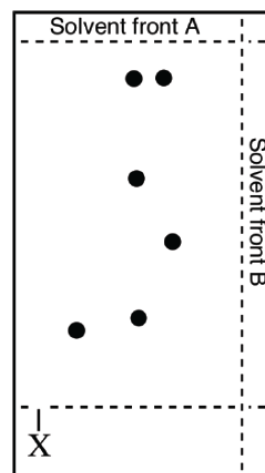
B



C



D



9. A *hypergolic* fuel system consisting of monomethylhydrazine, CH_3NHNH_2 , and dinitrogen tetroxide, N_2O_4 , (both liquids) is commonly used to propel space vehicles. The two reactants are combined stoichiometrically so that CO_2 , H_2O and N_2 are the only products formed (all gases under the same reaction conditions). How many moles of gas are produced from 100 mol of CH_3NHNH_2 ?

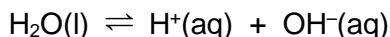
A 125

B 225

C 400

D 625

10. Pure water undergoes self-ionization according to the equation:



The equilibrium constant for the reaction is:

$$1.0 \times 10^{-14} \text{ at } 25^\circ\text{C} \quad \text{and} \quad 5.5 \times 10^{-13} \text{ at } 100^\circ\text{C}.$$

Which one of the following statements is correct?

- A** At 100°C, the pH of pure water is less than 7.0, but the $[H^+] = [OH^-]$.
- B** At 100°C, the pH of pure water is less than 7.0, and therefore $[H^+] > [OH^-]$.
- C** At 100°C, the pH of pure water is greater than 7.0, and therefore $[OH^-] > [H^+]$.
- D** At 100°C, the pH of pure water must be 7.0, and the $[H^+] = [OH^-]$.

11. In which one of the following compounds does manganese exist in the lowest oxidation state?

- A** Mn_2O_7 **B** $\text{Mn}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$
C KMnO_4 **D** MnO_2F

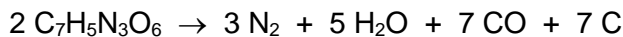
12. The enthalpy change of formation (ΔH_f°) for a species at 298 K is defined as the enthalpy change that accompanies the formation of one mole of a substance from its constituent elements in their standard states. Which one of the following species has $\Delta H_f^\circ = 0 \text{ kJ mol}^{-1}$?

- A** H₂O(l) **B** Na(s)
C CO₂(g) **D** O₃(g)

13. A Chemist requires 16.0 mol of liquid ethanol, $\text{C}_2\text{H}_5\text{OH}$, for a chemical reaction. What volume of ethanol should she use? The density of ethanol is 0.789 g cm^{-3} .

- A** 0.581 dm³ **B** 0.690 dm³
C 0.934 dm³ **D** 1.88 dm³

14. 2,4,6-trinitrotoluene (TNT, $C_7H_5N_3O_6$) can be used in synthetic organic chemistry, however, its use is limited because of its highly explosive nature. Upon detonation, TNT decomposes as a mixture of the following reactions:



When 20 mol of TNT was exploded with complete conversion into products, 30 mol of hydrogen gas was produced. How many moles of carbon monoxide were also produced?

- | | |
|---|-----|
| A | 28 |
| B | 49 |
| C | 72 |
| D | 100 |

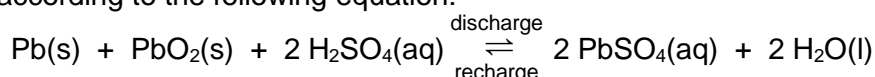
15. For a spontaneous reaction to occur at constant temperature and pressure, the Gibbs free energy (ΔG) must be negative. The Gibbs free energy combines two thermodynamic parameters into the Gibbs equation: $\Delta G = \Delta H - T\Delta S$, where ΔH is the change in enthalpy and ΔS is the change in entropy. What conditions of ΔH and ΔS for a chemical reaction will always give a spontaneous reaction?

- A ΔH positive, ΔS positive.
- B ΔH positive, ΔS negative.
- C ΔH negative, ΔS positive.
- D ΔH negative, ΔS negative.

16. Which one of the following species is both a hydrogen-bond donor and a hydrogen-bond acceptor?

- A CH_3OCH_3
- B HI
- C CH_3OH
- D CH_4

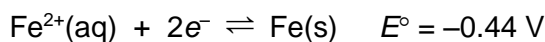
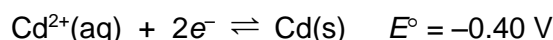
17. The most common batteries used in cars are lead-acid batteries that can be discharged and recharged according to the following equation:



When discharging, which species is the reducing agent?

- A Pb(s)
- B $\text{PbO}_2\text{(s)}$
- C $\text{SO}_4^{2-}\text{(aq)}$
- D $\text{PbSO}_4\text{(aq)}$

18. By referring to the standard reduction potentials below, which one of the species listed is the best oxidising agent?

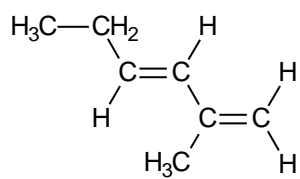


- A Cd(s)
- B $\text{Cu}^{2+}\text{(aq)}$
- C $\text{Fe}^{2+}\text{(aq)}$
- D Ni(s)

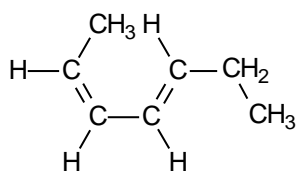
19. Which one of the following species does **not** have eight valence electrons surrounding the central atom?

- A CCl_4
- B NH_4^+
- C OF_2
- D BCl_3

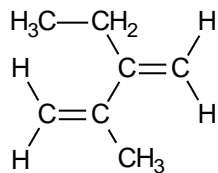
20. Which one of the following is **not** an isomer of the molecule shown below?



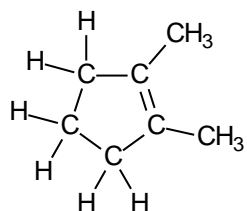
A



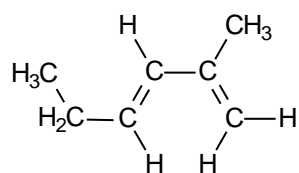
B



C



D



Group																	
I	II																
		1 H hydrogen 1															
7 Li lithium 3	9 Be beryllium 4											0 He helium 2					
23 Na sodium 11	24 Mg magnesium 12											19 F fluorine 9					
39 K potassium 19	40 Ca calcium 20	48 Ti titanium 22	45 Sc scandium 21	51 V vanadium 23	52 Cr chromium 24	55 Mn manganese 25	56 Fe iron 26	59 Co cobalt 27	59 Ni nickel 28	64 Cu copper 29	65 Zn zinc 30	70 Ga gallium 31	73 Ge germanium 32	75 As arsenic 33	79 Se selenium 34	80 Br bromine 35	84 Kr krypton 36
85 Rb rubidium 37	88 Sr strontium 38	91 Zr zirconium 40	89 Y yttrium 39	93 Nb niobium 41	96 Mo molybdenum 42	101 Ru ruthenium 44	103 Rh rhodium 45	106 Pd palladium 46	108 Ag silver 47	112 Cd cadmium 48	115 In indium 49	119 Sn tin 50	122 Sb antimony 51	128 Te tellurium 52	127 I iodine 53	131 Xe xenon 54	
133 Cs caesium 55	137 Ba barium 56	178 Hf hafnium 72	139 La lanthanum 57	181 Ta tantalum 73	184 W tungsten 74	186 Re rhenium 75	190 Os osmium 76	192 Ir iridium 77	197 Au gold 79	201 Hg mercury 80	204 Tl thallium 81	207 Pb lead 82	209 Bi bismuth 83	210 Po polonium 84	210 At astatine 85	222 Rn radon 86	
87 Fr francium	88 Ra radium	89 Ac actinium															

*58-71 Lanthanoid series

†90-103 Actinoid series

a = relative atomic mass

X = atomic symbol

b = proton (atomic) number

Key

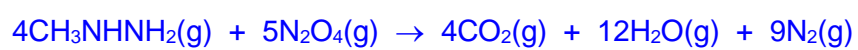
a	X	b
---	---	---

Key	a	X	b
	a = relative atomic mass	X = atomic symbol	b = proton (atomic) number

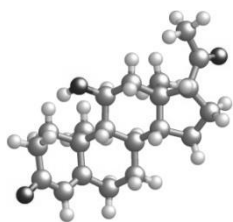
*58-71 Lanthanoid series
+90-103 Actinoid series

Answers

1. A
2. B
3. B
4. B
5. D
6. C
7. B
8. C
9. D



10. A
11. B
12. B
13. C
14. D
15. C
16. C
17. A
18. B
19. D
20. D



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Date: / /

Chemistry Olympiad Training for Secondary School Level – Part Five

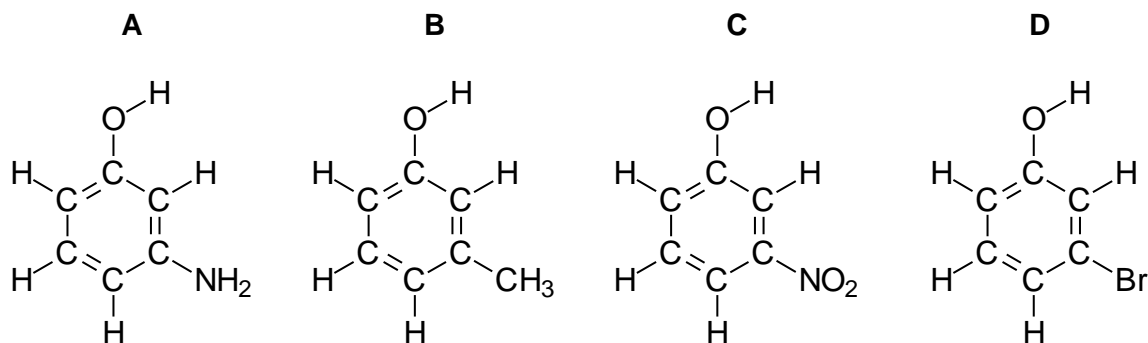
1. Which one of the following series of ions is arranged in order of increasing ionic radius?

- A $\text{Mg}^{2+} < \text{S}^{2-} < \text{Cl}^- < \text{K}^+ < \text{Ca}^{2+}$
B $\text{Mg}^{2+} < \text{Ca}^{2+} < \text{K}^+ < \text{Cl}^- < \text{S}^{2-}$
C $\text{S}^{2-} < \text{Cl}^- < \text{K}^+ < \text{Mg}^{2+} < \text{Ca}^{2+}$
D $\text{S}^{2-} < \text{Mg}^{2+} < \text{Ca}^{2+} < \text{Cl}^- < \text{K}^+$

2. Which one of the following compounds could **not** be obtained by oxidising phosphorus trifluoride, PF_3 ?

- A $\text{Na}_4\text{P}_2\text{O}_7 \cdot 10\text{H}_2\text{O}$ B $\text{H}_4\text{P}_2\text{O}_6$
C $(\text{NH}_4)_2\text{HPO}_3 \cdot \text{H}_2\text{O}$ D $\text{Ca}_5(\text{PO}_4)_3\text{F}$

3. Ethanoic acid was heated with an unknown compound **X** and a catalytic amount of sulfuric acid. The reaction mixture was shown by mass spectrometry to contain a compound of molar mass 193 g mol^{-1} . Which one of the following could be compound **X**?



4. Equal masses of each of the following compounds were treated with excess hydrochloric acid. Which one produced the greatest volume of carbon dioxide?

- A Sodium carbonate
B Magnesium carbonate
C Potassium carbonate
D Calcium carbonate

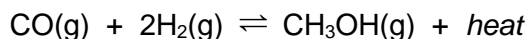
- 9.** The following is a list of selected standard reduction potentials:



By referring to the standard reduction potentials above, which one of the following species is the best oxidising agent?

- A** Cd(s) **B** Zn²⁺(aq)
C Ni²⁺(aq) **D** Zn(s)

- 10.** It is known that carbon monoxide reacts exothermically with hydrogen gas to form methanol at 400°C, in the presence of a catalyst:



A mixture of carbon monoxide, hydrogen gas and methanol placed under conditions described above achieves equilibrium in a closed container. If the reaction temperature is changed to 450°C, which of the following statements is correct?

- A** The total number of molecules in the container decreases.
- B** The reaction rates of both the forward and reverse reactions remains constant.
- C** The average molecular mass of the gaseous mixture decreases.
- D** The total pressure within the container decreases.

11. A gaseous mixture containing ethane and methane underwent complete combustion to produce 5.28 g of carbon dioxide and 3.78 g of water. What is the volume ratio of ethane to methane in the original mixture?

- A** 1:1 **B** 1:2
C 2:1 **D** 1:4

- 12.** Given the following table of electronegativities, which one of the following bonds is most polar?

Element	P	C	S	N	Cl
Electronegativity	2.19	2.55	2.58	3.04	3.16

- A** P-S **B** S-N
C S-Cl **D** C-Cl

13. The enthalpy change of which reaction corresponds to ΔH_f° for $\text{Na}_2\text{CO}_3(\text{s})$ at 298 K?

- A $2 \text{Na}(\text{s}) + \text{C}(\text{s}) + \frac{3}{2} \text{O}_2(\text{g}) \rightarrow \text{Na}_2\text{CO}_3(\text{s})$
- B $\text{Na}_2\text{O}(\text{s}) + \text{CO}_2(\text{g}) \rightarrow \text{Na}_2\text{CO}_3(\text{s})$
- C $2 \text{Na}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{Na}_2\text{CO}_3(\text{s})$
- D $2 \text{Na}^+(\text{aq}) + 2 \text{OH}^-(\text{aq}) + \text{CO}_2(\text{g}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$

14. A sample of oxygen gas and a sample of an unknown gas are weighed separately in the same evacuated flask. Use the data given to find the molar mass of the unknown gas. Assume that all experiments are conducted at the same temperature and pressure.

mass of evacuated flask	124.46 g
mass of flask + oxygen	125.10 g
mass of flask + unknown gas	125.34 g

- A 22 g mol^{-1}
- B 38 g mol^{-1}
- C 44 g mol^{-1}
- D 84 g mol^{-1}

15. What is the most effective way to condense a gas?

- A Decrease the temperature and increase the pressure.
- B Decrease the temperature and decrease the pressure.
- C Increase the temperature and decrease the pressure.
- D Increase the temperature and increase the pressure.

16. For a rate law of the form:

$$\text{rate} = k \times [\text{A}]^m \times [\text{B}]^n$$

the exponents m and n are obtained from:

- A Changes in the rate of reaction with changing temperature.
- B The coefficients of A and B in the balanced chemical equation.
- C The concentrations of A and B in a single experiment.
- D Changes in the rate of reaction for different concentrations of A and B.

17. Which reaction occurs with the greatest increase in entropy?

- A $2 \text{H}_2\text{O}(\text{l}) \rightarrow 2 \text{H}_2(\text{g}) + \text{O}_2(\text{g})$
- B $2 \text{NO}(\text{g}) \rightarrow \text{N}_2(\text{g}) + \text{O}_2(\text{g})$
- C $\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$
- D $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2 \text{HCl}(\text{g})$

18. The rates of which reactions are increased when temperature is increased?

I exothermic

II endothermic

A I only.

B II only.

C Both I and II.

D Neither I nor II.

19. The boiling points of the halogens, F_2 , Cl_2 , Br_2 and I_2 , increase in that order. This is best attributed to differences in:

A Covalent bond strengths.

B Dipole forces.

C van der Waals forces.

D Hydrogen bonds.

20. Which statement is true for a reaction at equilibrium?

A All reactions cease.

B The reaction has reached completion.

C The rates of the forward and reverse reactions are equal.

D The amount of product equals the amount of reactant.

The Periodic Table of the Elements

Group																	
I	II											III	IV	V	VI	VII	0
<div>1 H hydrogen 1</div>																	
7 Li lithium 3	9 Be beryllium 4											11 B boron 5	12 C carbon 6	14 N nitrogen 7	16 O oxygen 8	19 F fluorine 9	20 Ne neon 10
23 Na sodium 11	24 Mg magnesium 12											27 Al aluminium 13	28 Si silicon 14	31 P phosphorus 15	32 S sulfur 16	35.5 Cl chlorine 17	40 Ar argon 18
39 K potassium 19	40 Ca calcium 20	48 Ti titanium 22	45 Sc scandium 21	51 V vanadium 23	52 Cr chromium 24	55 Mn manganese 25	56 Fe iron 26	59 Co cobalt 27	59 Ni nickel 28	64 Cu copper 29	65 Zn zinc 30	70 Ga gallium 31	73 Ge germanium 32	75 As arsenic 33	79 Se selenium 34	80 Br bromine 35	84 Kr krypton 36
85 Rb rubidium 37	88 Sr strontium 38	91 Zr zirconium 40	89 Y yttrium 39	93 Nb niobium 41	96 Mo molybdenum 42	101 Ru ruthenium 44	103 Rh rhodium 45	108 Ag silver 47	106 Pd palladium 46	112 Cd cadmium 48	115 In indium 49	119 Sn tin 50	122 Sb antimony 51	127 I iodine 53	128 Te tellurium 52	131 Xe xenon 54	131 Xe xenon 54
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Fr francium 87	Ra radium 88	Ac actinium 89	Fr francium 87	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89	Ac actinium 89
*58-71 Lanthanoid series †90-103 Actinoid series																	

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	162 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	238 U uranium 92	238 U uranium 92	238 U uranium 92	238 U uranium 92	238 U uranium 92	238 U uranium 92	238 U uranium 92	238 U uranium 92	238 U uranium 92	238 U uranium 92	238 U uranium 92	238 U uranium 92

a

X

b

a = relative atomic mass

X = atomic symbol

b = proton (atomic) number

Key

a

X

b

a = relative atomic mass

X = atomic symbol

b = proton (atomic) number

*58-71 Lanthanoid series
+90-103 Actinoid series

Answers

1. B
2. C
3. A
4. B
5. C
6. B
7. C
8. A
9. C
10. C
11. B
12. D
13. A
14. C
15. A
16. D
17. A
18. C
19. C
20. C