NANYANG			Name: ()
	and the second	Chem!stry	Class:	
· 法 拼 法 推	appe		Date: / /	

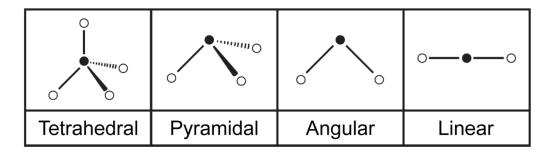
Chemistry Olympiad Training for Secondary School Level – Part One

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:

$$E(g) \rightarrow E^{+}(g) + e^{-}$$

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.



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:

 $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -78 \text{ kJ mol}^{-1}$

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?

$$\mathbf{A} \quad \mathbf{Zn} + \mathbf{CuSO}_4 \rightarrow \mathbf{ZnSO}_4 + \mathbf{Cu}$$

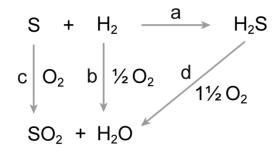
- $\textbf{B} \quad 2CO \ \rightarrow \ C \ + \ CO_2$
- $\mathbf{C} \quad 4\mathbf{S} + 5\mathbf{O}_2 \rightarrow 2\mathbf{SO}_2 + 2\mathbf{SO}_3$
- $\textbf{D} \quad MnO_2 \ \textbf{+} \ \textbf{4}\textbf{HCl} \ \rightarrow \ MnCl_2 \ \textbf{+} \ \textbf{2}\textbf{H}_2\textbf{O} \ \textbf{+} \ \textbf{Cl}_2$
- 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 $\Delta S^{\circ} > 0$?
 - $\textbf{A} \quad \textbf{S}_8 (\textbf{I}) \ \rightarrow \ \textbf{S}_8 (\textbf{s})$
 - $\textbf{B} \quad H_2\left(g\right) \ + \ O_2\left(g\right) \ \rightarrow H_2O_2\left(l\right)$

 - $\textbf{D} \quad \mathsf{PCI}_5 \ (g) \ \rightarrow \ \mathsf{PCI}_3 \ (g) \ + \ \mathsf{CI}_2 \ (g)$

7. Study the following reactions:

$S(s) + H_2(g) \rightarrow H_2S(g)$	∆H = a
$H_2 \ (g) \ + \ {}^1\!/_2 O_2 \ (g) \ \to \ H_2 O \ (I)$	$\Delta H = \mathbf{b}$
$S~(s)~+~O_2~(g)~\rightarrow~SO_2~(g)$	$\Delta H = c$
$H_2S(g) + 1^{1}/_2O_2(g) \rightarrow H_2O(I) + SO_2(g)$	$\Delta H = d$

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**?

- $\mathbf{A} \quad \mathbf{a} = \mathbf{b} + \mathbf{c} \mathbf{d}$
- **B** a = d b c
- \mathbf{C} a = b c d
- \mathbf{D} a = d + c b
- 8. A reaction takes place in two stages:

Stage 1:

 $S_2O_8{}^{2-}\,(aq) \ + \ 2I^-\,(aq) \ + \ 2Fe^{2+}\,(aq) \ \rightarrow \ 2SO_4{}^{2-}\,(aq) \ + \ 2I^-\,(aq) \ + \ 2Fe^{3+}\,(aq)$

Stage 2:

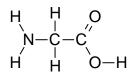
 $2SO_4^{2-}(aq) + 2I^{-}(aq) + 2Fe^{3+}(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq) + 2Fe^{2+}(aq)$

Which ion is the catalyst in this reaction?

Α :	$S_2O_8^{2-}$	(aq)	В	l⁻ (aq)
-----	---------------	------	---	---------

C Fe²⁺ (aq) **D** SO₄²⁻ (aq)

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.

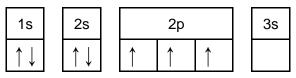


The table contains information about the attraction of some atoms for bonded pairs of electrons.

Atom	Relative Attraction for a Bonding Pair of Electrons
н	2.2
С	2.5
Ν	3.0
0	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:



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

2p 2s 3s 1s Α 1 Ţ ↑ ↑ 2s 2p 3s 1s В 1 ↑ 1 1s 2s 2p 3s С 1 ↓ 1 1 1 Î ↓ 2s 2p 3s 1s D

11. A simple battery can be made by connecting two different half-cells together. When the two different half-cells are connected, a potential difference is produced between them.

Connecting a zinc half-cell $[Zn(s) / Zn^{2+}(aq)]$ to a copper half-cell $[(Cu(s) / Cu^{2+}(aq)]$ produces a potential difference of 1.10 volts.

The potential difference produced by two half-cells can be calculated from their *standard electrode potentials*.

Half-cell	Standard Electrode Potential / V
[Mg(s) / Mg ²⁺ (aq)]	-2.38
[Zn(s) / Zn ²⁺ (aq)]	-0.76
[Cu(s) / Cu ²⁺ (aq)]	+0.34
[Ag(s) / Ag⁺(aq)]	+0.80

Which combination of half-cells will generate a potential difference of 1.56 V?

A $[Mg(s) / Mg^{2+}(aq)]$ and $[Zn(s) / Zn^{2+}(aq)]$

- **B** $[Mg(s) / Mg^{2+}(aq)]$ and $[Cu(s) / Cu^{2+}(aq)]$
- **C** $[Zn(s) / Zn^{2+}(aq)]$ and $[Ag(s) / Ag^{+}(aq)]$
- **D** $[Cu(s) / Cu^{2+}(aq)]$ and $[Ag(s) / Ag^{+}(aq)]$
- **12.** The rate of decomposition of hydrogen peroxide is first order for H_2O_2 . At $[H_2O_2] = 0.150 \text{ mol dm}^{-3}$, the decomposition rate was measured to be $4.83 \times 10^{-6} \text{ mol dm}^{-3} \text{ s}^{-1}$. What is the rate constant for the reaction?
 - A $2.15 \times 10^{-4} \, \text{s}^{-1}$ B $3.22 \times 10^{-5} \, \text{s}^{-1}$ C $4.83 \times 10^{-6} \, \text{s}^{-1}$ D $7.25 \times 10^{-7} \, \text{s}^{-1}$
- **13.** Which class of organic compound does not contain oxygen?

Α	Alcohol	В	Amide
С	Amine	D	Ketone

- 14. Which of the following compounds could contain exactly one triple bond?
 - **A** C_5H_{10} **B** C_5H_{12}
 - **C** C_6H_{10} **D** C_6H_{12}

- **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:

 $H_2O(I) \rightleftharpoons H^+(aq) + OH^-(aq)$

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

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

What is the pH of an aqueous solution that contains 0.0100 mol dm⁻³ NaOH?

Α	1 × 10 ⁻⁷	В	7
С	12	D	14

------r

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

	2NO (g) + O ₂ (g)	$\rightarrow 2NO_2$ (g)
1 / mol dm ⁻³	[O₂] / mol dm ⁻³	Initial Rate of NO ₂ Forr

Experiment	[NO] / mol dm ⁻³	[O ₂] / mol dm ⁻³	Initial Rate of NO ₂ Formation / mol dm ⁻³ 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 O_2 (g) = third order

- **B** NO (g) = first order O_2 (g) = second order
- **C** NO (g) = second order O_2 (g) = first order
- **D** NO (g) = third order O_2 (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:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

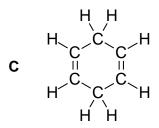
What is the equilibrium constant for this reaction?

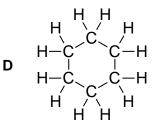
A
$$K_{c} = \frac{[SO_{3}]^{2}}{[SO_{2}]^{2} \times [O_{2}]}$$

B $K_{c} = \frac{[SO_{2}]^{2} \times [O_{2}]}{[SO_{3}]^{2}}$
C $K_{c} = \frac{2[SO_{3}]}{2[SO_{2}] \times [O_{2}]}$
D $K_{c} = \frac{2[SO_{2}] \times [O_{2}]}{2[SO_{3}]}$

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







20. Given the enthalpy changes:

$\textbf{A} + \textbf{B} \rightarrow \textbf{C}$	$\Delta H = -35 \text{ kJ mol}^{-1}$
$A + D \rightarrow E + F$	ΔH = +20 kJ mol ⁻¹
$F \rightarrow C + E$	$\Delta H = +15 \text{ kJ mol}^{-1}$

What is ΔH for the reaction $2A + B + D \rightarrow 2F$?

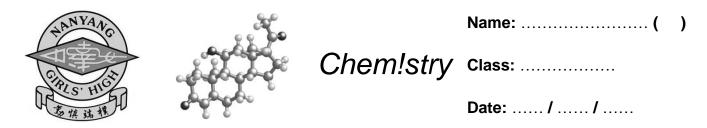
- A 0 kJ mol⁻¹
- B -30 kJ mol⁻¹
- **C** –40 kJ mol⁻¹
- **D** –70 kJ mol⁻¹

The Periodic Table of the Elements

								Gn	Group								
	I											III	N	Λ	N	NI	0
							← I	12									4 He
							hydrogen 1										helium 2
7	6	 										11	12	14	16	19	20
C	Be											В	U	z	0	ш	Ne
lithium 3	beryllium 4											5 boron	carbon 6	nitrogen 7	oxygen 8	fluorine 9	10
23	24	T										27	28	31	32	35.5	40
Na	Mg											AI	Si	Р			Ar
sodium 11	magnesium 12	F										aluminium 13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
39	40	45	48	51	52	55	56	59	59	29	65	20	73	75			84
¥		_	F	>		Mn	Fe	ပိ	ī	Cu	Zn		Ge		Se	Br	Kr
potassium	calcium	scandium	titanium	muipeux		chromium manganese	90	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton
10	70 VU	00	77	52	74	07	107	1001	207	200	20		25	3	5	201	201
22	8 6	80 >	19	SUP NIP	06 06	I F		103	001	80L	711	CLL	ALL S	122	128	121	131
	ō	1	7		DIVI O		_	Ē		DY.	3	H	5	00	D -	1	PC
37 37	strontium 38	39	Zirconium 40	41	molybdenu m 47	technetium 43	44	45	palladium 46	silver 47	cadmium 48	49	50 tin	antimony 51	tellunum 52	53	54 xenon
133	137	139	178	181	184	186	190	192	195	197	201	204	207	209	1	1	1
Cs	Ba	La	Ŧ	Ta	M	Re	Os	Ir		Au	Ρđ	TI	Pb	Bi	Po	At	Rn
caesium 55	barium 56	57 * 7	hafnium 72	tantalum 73	tungsten 74	rhenium 75	osmium 76	iridium 77	platinum 78	plog 79	mercury 80	thallium 81	lead 82	bismuth 83	polonium 84	astatine 85	radon 86
1	1	1			Ċ,			2						e,			1
Ŀ	Ra	Ac															
francium 87	88	actinium 89 †															
*58-71 L	anthano	*58-71 Lanthanoid series															
+90-103	†90-103 Actinoid series	l series															
			8	140	141	144	1	150	152	157	159	162	165	167	169	173	175
				Ce	Å.	PN	Pm			Gd	Tb	D	P	ш		Υb	Lu
				cerium 58	59	60	59 60 61 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70	Iutetium 71
Key a		a = relative atomic mass	mass	232	1	238	1		1	1	1	1		1	1	1	I
×		X = atomic symbol	160	Ъ	Ра		dN	Pu		Ca	BK	പ്	Es		pW	No	
	ot:	b = proton (atomic) number		thorium	protactinium 01	0.0	neptunium	plutonium	americium	curium	berkelium 07	californium	californium einsteinium	100	mendelevium	nobelium 100	lawrencium 102
2	1		1	De	10	26	22	5		00	10	20	22	001	101	102	201

Answers

1. С 2. С 3. С 4. В 5. С 6. D 7. Α 8. С 9. D 10. B 11. C 12. <mark>B</mark> 13. C 14. C 15. A 16. C 17. C 18. A 19. B 20. B if... $A + B \rightarrow C$ and... $A + D \rightarrow E + F$ then... $2A + B + D \rightarrow C + E + F$ $\Delta H = (-35 \text{ for } A + B) + (+20 \text{ for } A + D) = -15 \text{ kJ}$ C + E can react to form the second molecule of F forward reaction: $F \rightarrow C + E \Delta H = +15 \text{ kJ}$ reverse reaction: $C + E \rightarrow F \Delta H = -15 \text{ kJ}$ overall enthalpy change = (-15) + (-15) = -30 kJ



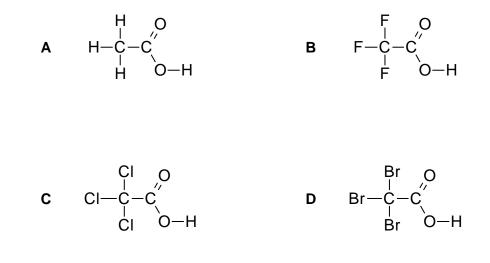
Chemistry Olympiad Training for Secondary School Level - Part Two

1. Study the three chemical reactions shown below:

$$\begin{array}{rcl} \mathsf{H}^{+} \ + \ :\mathsf{NH}_{3} \ \rightarrow \ (\mathsf{H}:\mathsf{NH}_{3})^{+} \\ \\ \mathsf{AlCI}_{3} \ + \ :\mathsf{CI}_{2} \ \rightarrow \ (\mathsf{CI}:\mathsf{AlCI}_{3})^{-} \ + \ \mathsf{CI}^{+} \\ \\ & \mathsf{BF}_{3} \ + \ :\mathsf{NH}_{3} \ \rightarrow \ \mathsf{F}_{3}\mathsf{B}:\mathsf{NH}_{3} \end{array}$$

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?



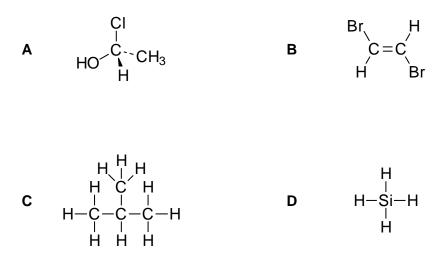
- **3.** The enthalpy change, under standard conditions, for which one of the reactions below would be equal to the ΔH°_{f} of NaOH (s)?

 - **B** Na(s) + $\frac{1}{2}O_2(g) + \frac{1}{2}H_2(g) \rightarrow NaOH(s)$

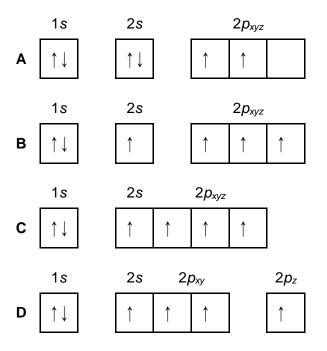
C Na(s) +
$$\frac{1}{2}H_2O_2(I) \rightarrow NaOH(s)$$

D Na⁺(aq) + OH⁻(aq) \rightarrow NaOH(s)

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

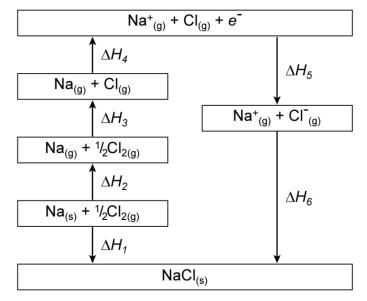


5. Which one of the following electronic arrangements shows sp^3 hybridisation in carbon?



- **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
 - $\boldsymbol{C} \quad \text{Gypsum, } CaSO_4{\cdot}2H_2O$
 - 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, CH₂O?

Α	-2	В	0
С	+2	D	+4

- **10.** Which molecule is correctly matched with its shape as predicted by as predicted by valence shell electron pair repulsion theory (VSEPRT)?
 - A CH₄ octahedral
 - **B** NH₃ linear
 - $\label{eq:constraint} \textbf{C} \quad \mathsf{PCI}_5 \qquad \text{trigonal bipyramidal}$
 - **D** SF₆ tetrahedral

11. A sulfur atom in the ground state has the electronic configuration:

 $1s^2 2s^2 2p^6 3s^2 3p^4$

How many orbitals are occupied by at least one electron?

- A 5 B 9 C 11 D 16
- **12.** The molecules in a sample of pure liquid dichloromethane, CH₂Cl₂, experience which of the following intermolecular forces:
 - I van der Waals forces
 - II dipole-dipole forces
 - III Hydrogen bonds
 - AI onlyBII onlyCI and II onlyDI, II and III
- **13.** What is the equilibrium expression for the reaction given below?

$$2C(s) + O_2(g) \rightleftharpoons 2CO(s)$$

A
$$K = \frac{2[CO]}{2[C] \times [O_2]}$$
 B $K = \frac{2[CO]}{[O_2]}$

$$\mathbf{C} \qquad \mathcal{K} = \frac{[\mathrm{CO}]^2}{[\mathrm{C}]^2 \times [\mathrm{O}_2]} \qquad \qquad \mathbf{D} \qquad \mathcal{K} = \frac{[\mathrm{CO}]^2}{[\mathrm{O}_2]}$$

14. Consider the following reactions:

$$I \quad 2NO_2(g) \rightarrow N_2(g) + 2O_2(g)$$

II $2IBr(g) \rightarrow I_2(s) + Br_2(l)$

For which reaction is $\Delta S^{\circ} < 0$?

- A I only B II only
- C Both I and II D Neither I nor II

15. Given chemical equations for these reactions:

$S(s) \ + \ O_2(g) \ \rightarrow \ SO_2(g)$	ΔH° = –296.8 kJ mol ⁻¹
$H_2(g) \ + \ {}^1\!/_2O_2(g) \ \to \ H_2O(I)$	$\Delta H^{\circ} = -285.8 \text{ kJ mol}^{-1}$
$H_2(g) + S(s) \rightarrow H_2S(g)$	$\Delta H^{\circ} = -20.6 \text{ kJ mol}^{-1}$

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

		$2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(I) + 2SO_2(g)$
Α	–603.2 kJ mol ⁻¹	B –562.0 kJ mol ⁻¹
С	–1206.4 kJ mol⁻¹	D –1124.0 kJ mol ⁻¹

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

Α	K ⁺	В	Ca ²⁺
С	P ³⁻	D	S ^{2–}

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

$$\mathbf{A}(g) + \mathbf{B}(g) \rightarrow \mathbf{C}(g)$$

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 = $k \times [A]$
- **C** Rate = $k \times [A]^2$

B Rate = $k \times [A] \times [B]$

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

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

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

- $\textbf{B} \quad 3Zn(s) \ + \ 2Cr^{3+}(aq) \ \rightarrow \ 3Zn^{2+}(aq) \ + \ 2Cr(s)$
- **D** Zn(s) + Fe²⁺(aq) \rightarrow Zn²⁺(aq) + Fe(s)

20. The ideal gas equation is given below:

$$PV = nRT$$

R = gas constant = 8.314 JK⁻¹mol⁻¹
 n = amount of gas / mol
f oxygen gas occupy at a pressure

What volume does 64.0 g of oxygen gas occupy at a pressure of 101 000 pa and a temperature of 100 $^\circ\text{C}?$

Note: $A_{\rm r}[{\rm O}] = 16.0$

Α	0.0165 m ³	В	0.0614 m ³
С	0.123 m ³	D	0.0329 m ³

The Periodic Table of the Elements

								G	Group								
	I											III	N	Ν	VI	NI	0
							+ I										4 He
							hydrogen 1	-									helium 2
7	6	[11	12	14	16	19	20
1	Be											8	U	z	0	щ	Ne
lithium 3	beryllium 4											5 5	carbon 6	nitrogen 7	oxygen 8	fluorine 9	10
23	24	Ī										27	28	31	32	35.5	40
Na	Mg											AI	Si	٩			Ar
sodium 11	magnesium 12	F										aluminium 13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
39	40	45	48	51	52	55	56	59	59	64	65	20	73	75			84
¥	Ca	Sc	F	>		Mn	Fe	ů	ïz	Cu	Zn	Ga	Ge		Se	Br	Kr
potassium	calcium	scandium	titanium	muipeux		chromium manganese	90	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton
13 05	00	00	14	50	47	- C	104	100	100	100	00	145	110	3	100	101	104
20	8 6	20 >	24	SP 414	OS ON	۱ ۴		102	000	100	711	61	200	771	120	171	131
	ก	L	1	QN	OINI		_		ם ז	AG	3	u :		00	e	1	Ae
37 37	strontium 38	39	zirconium 40	41	m M A 7	technetium 43	ruthenium 44	45	palladium 46	silver 47	cadmium 48	49	50 tin	antimony 51	tellunum 52	53	xenon 54
133	137	139	178	181	184	186	190	192	195	197	201	204	207	209	1	1	J
Cs	Ba	La	Ŧ	Ta	M	Re	Os	Ir		Au	Hg	T1	Pb	Bi	Po	At	Rn
caesium 55	barium 56	57 * 7	hafnium 72	tantalum 73	tungsten 74	rhenium 75	osmium 76	iridium 77	platinum 78	79 ^{gold}	mercury 80	thallium 81	lead 82	bismuth 83	polonium 84	astatine 85	radon 86
1	1	Ι.			Ĉ,			2			2			e.			
Fr	Ra	Ac															
87	88	89 †															
*58-71 L	anthano	*58-71 Lanthanoid series															
190-103	†90-103 Actinoid series	l series															
			3	140	141	41	1	150	152	157	159	162	165	167	169	173	175
				Se	Ъ	PN	Pm	Sm	Ш	Gd	Tb	2	위	ш		Υb	Lu
				cerium 58	praseodymium 59	neodymium 60	59 60 61 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70	Iutetium 71
Key a		a = relative atomic mass		232	1	238	1		I	1	1	1			1	1	I
×		X = atomic symbol		Ч	Ра	D	dN	Pu		Cm	Ŗ		Es		pM		٦
4	015	b = proton (atomic) number		thorium	protactinium 01	uraniun	n neptunium	plutonium	americium	curium	berkelium 07		califomium einsteinium	1 fermium	mendelevium	nobelium	lawrencium 102
2	٦			20	21		20	5		20	21	20	22	201	101	IUZ	100

Answers

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

8

NANYANG			Name: ()
Contraction of the second	and a constant	Chem!stry	Class:	
· 本族法律	oppos		Date: / /	

Chemistry Olympiad Training for Secondary School Level - Part Three

- 1. Which one of the following substances has the highest melting point?
 - A
 Li₂O
 B
 MgO

 C
 CO₂
 D
 N₂O₅

2. Which one of the following nitrogen halides is least stable thermodynamically?

Α	NF ₃	В	NCl ₃
С	NBr ₃	D	NΙ₃

3. Which one of the following organic compounds is least soluble in water?

Α	Butan-1-ol	В	Ethanol
С	Methanol	D	Propan-1-ol

 Use the information provided to calculate the standard enthalpy change of formation for ethyne, C₂H₂(g), in kJ mol⁻¹.

 $\begin{array}{ll} C_2H_2(g) \ + \ {}^{5}\!/_2O_2(g) \ \to \ 2CO_2(g) \ + \ H_2O(l) & \Delta H^\circ = -1299.5 \\ \\ C(s) \ + \ O_2(g) \ \to \ CO_2(g) & \Delta H^\circ = -393.5 \\ \\ H_2(g) \ + \ {}^{1}\!/_2O_2(g) \ \to \ H_2O(l) & \Delta H^\circ = -285.8 \end{array}$

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

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

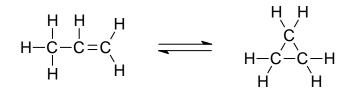
- 6. In order to calculate the lattice energy of NaCl using a Born-Haber cycle, which value is not needed?
 - A The enthalpy of sublimation of Na(s).
 - **B** The first ionisation energy of Cl(g).
 - **C** The bond dissociation energy of $Cl_2(g)$.
 - **D** The enthalpy of formation of NaCl(s).
- 7. 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?

Α	rate = $k[\mathbf{X}]^2$	В	rate = <i>k</i> [Y] ²
С	rate = <i>k</i> [X][Y]	D	rate = $k[\mathbf{X}][\mathbf{Y}]^2$

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.

Α	I only.	В	II only.
С	Both I and II.	D	Neither I nor II.

9. Which ion is not isoelectric with argon?

Α	S ²⁻	В	K⁺
С	Sc ²⁺	D	Ti ⁴⁺

10. Which substance will form hydrogen bonds to water molecules but will not form hydrogen bonds with its own molecules?

Α	HF	В	C_2H_5OH
С	CH ₃ NH ₂	D	CH ₃ OCH ₃

- **11.** What is the number of π -bonds in butenedioic acid, C₄H₄O₄?
 - Α 1 В 2 С 3 4 D
- 12. In which list are the ions arranged in order of increasing size?
 - **A** $F^- < S^{2-} < Al^{3+} < Mg^{2+}$ ${\bf B} \quad F^- < S^{2-} < Mg^{2+} < Al^{3+}$ **C** Mg²⁺ < F^- < Al³⁺ < S²⁻ **D** $Al^{3+} < Mg^{2+} < F^- < S^{2-}$
- **13.** The pH of a saturated solution of $Fe(OH)_2$ is 8.67. What is the K_{sp} for $Fe(OH)_2$?

	-	
		$Fe(OH)_2(s) \rightarrow Fe^{2+}(aq) + 2OH^{-}(aq)$
		$\mathcal{K}_{sp} = [Fe^{2+}(aq)] \times [OH^{-}(aq)]^2$
Α	$5 imes 10^{-6}$	B 2 × 10 ⁻¹¹
С	1 × 10 ⁻¹⁶	D 5×10^{-17}

- 14. Molecules of which type(s) do not contain a C=O bond?
 - Amide
 - Ш Amine
 - III Ether
 - IV Ester
 - A II only. B I and IV only.
 - II and III only. С

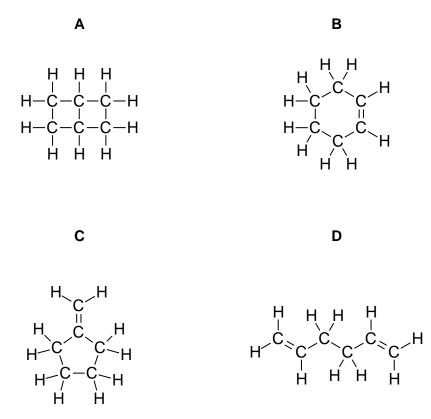
- III and IV only. D
- 15. Bond energies for hydrogen and nitrogen are given in the table below:

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

What is the $\Delta H_{f^{\circ}}$ for N₂H₄(g) in kJ mol⁻¹?

 $N_2(g) + 2H_2(g) \rightarrow N_2H_4(g)$ **B** +99 A +156 **C** –99 **D** –156

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



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

 $UO_2(C_2H_3O_2)_2 \cdot NH_4C_2H_3O_2 \cdot 6H_2O$

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

Α	5.58%	В	16.8%
С	22.3%	D	39.1%

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

С	Н	Ν	0
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** C₁₅H₁₀N₆O₁₁ **C** C₁₆H₁₂N₅O₁₁

- **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(NO₃)₂(aq) are combined with a silver half-cell in which the following reaction takes place:

The Periodic Table of the Elements

								Gn	Group								
	I											III	N	Λ	N	NI	0
							← I	12									4 He
							hydrogen 1										helium 2
7	6	[11	12	14	16	19	20
C	Be											В	U	z	0	ш	Ne
lithium 3	beryllium 4											5 boron	carbon 6	nitrogen 7	oxygen 8	fluorine 9	10
23	24	T										27	28	31	32	35.5	40
Na	Mg											AI	Si	Р			Ar
sodium 11	magnesium 12	F										aluminium 13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
39	40	45	48	51	52	55	56	59	59	29	65	20	73	75			84
¥		_	F	>		Mn	Fe	ပိ	ī	Cu	Zn		Ge		Se	Br	Kr
potassium	calcium	scandium	titanium	muipeux		chromium manganese	90	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton
10	70 VU	00	77	52	74	07	107	1001	207	200	20		25	3	5	201	201
22	8 6	80 >	19	SUP NIP	06 06	I F		103	001	80L	711	CLL	ALL S	122	128	121	131
	ō	1	7		DIVI O		_	Ē		DY.	3	H	En :	00	D -	1	PC
37 37	strontium 38	39	Zirconium 40	41	molybdenu m 47	technetium 43	44	45	palladium 46	silver 47	cadmium 48	49	50 tin	antimony 51	tellunum 52	53	54 xenon
133	137	139	178	181	184	186	190	192	195	197	201	204	207	209	1	1	1
Cs	Ba	La	Ŧ	Ta	M	Re	Os	Ir		Au	Ρđ	Τl	Pb	Bi	Po	At	Rn
caesium 55	barium 56	57 * 7	hafnium 72	tantalum 73	tungsten 74	rhenium 75	osmium 76	iridium 77	platinum 78	plog 79	mercury 80	thallium 81	lead 82	bismuth 83	polonium 84	astatine 85	radon 86
1	1	1			Ċ,			2						e,			1
Ŀ	Ra	Ac															
francium 87	88	actinium 89 †															
*58-71 L	anthano	*58-71 Lanthanoid series															
190-103	†90-103 Actinoid series	l series															
			8	140	141	144	1	150	152	157	159	162	165	167	169	173	175
				Ce	Å.	PN	Pm			Gd	Tb	D	P	ш		Υb	Lu
				cerium 58	59	60	59 60 61 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70	Iutetium 71
Key a		a = relative atomic mass	mass	232	1	238	1		1	1	1	1		1	1	1	I
×		X = atomic symbol	160	Ъ	Ра		dN	Pu		Ca	BK	പ്	Es		pW	No	
	ot:	b = proton (atomic) number		thorium	protactinium 01	0.0	neptunium	plutonium	americium	curium	berkelium 07	californium	californium einsteinium	100	mendelevium	nobelium 100	lawrencium 102
2	1		1	De	10	26	22	5		00	10	20	22	001	101	102	201

Answers

- 1. B
- 2. D
- 3. A
- 4. C
- 5. <mark>B</mark>
- 6. B
- 7. D
- 8. D
- 9. <mark>C</mark>
- 10. <mark>D</mark>
- 11. <mark>C</mark>
- 12. <mark>D</mark>
- 13. D
- 14. C 15. B
- 1**J**. L
- 16. A 17. D
- 18. B
- 10. 0
- 19. D 20. D

NANYANC			Name: ()
Contraction of the second	and a second	Chem!stry	Class:	
· 表供站样	စ်ခုံစုပ်ပ		Date: / /	

Chemistry Olympiad Training for Secondary School Level – Part Four

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

$$\mathcal{K}_{a} = \frac{[H^{+}] \times [A^{-}]}{[HA]}$$

Which one of the following acids is the strongest acid?

Α	Oxalic acid	$H_2C_2O_4$	$Ka = 5.90 \times 10^{-2}$
в	Hydrofluoric acid	HF	$Ka = 7.20 \times 10^{-4}$
С	Ethanoic acid	CH₃COOH	$Ka = 1.76 \times 10^{-5}$
D	Phenol	C ₆ H₅OH	$Ka = 1.60 \times 10^{-10}$

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

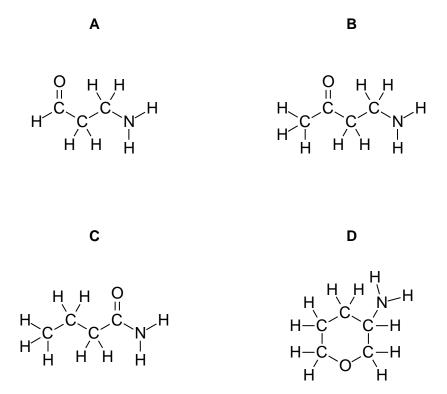
How many π -bonding electrons are there in a single molecule of but-3-yn-1-ene?

3. Phenolphthalein is a common indicator that is used for acid-base titrations. Phenolphthalein's percentage composition by mass is given below:

What is the empirical formula of phenolphthalein?

- **A** C₇H₃O₂ **B** C₁₀H₇O₂
- **C** $C_{15}H_4O_2$ **D** $C_5H_2O_3$

4. Which molecule contains both an amine and a ketone?



- **5.** Tellurium has a lower atomic number than iodine, but it has a higher relative atomic mass than iodine. This is because:
 - A Tellurium has more electrons than iodine.
 - **B** Tellurium has more isotopes than iodine.
 - **C** One of the isotopes of tellurium has more neutrons than one of the isotopes of iodine.
 - D The main isotopes of tellurium have more nucleons than the main isotopes of iodine.
- 6. How many electrons are transferred from 10I⁻ to 2MnO₄⁻ ions in the following redox reaction?

$$2 \text{ MnO}_4(aq) + 16 \text{ H}^+(aq) + 10 \text{ I}^- \rightarrow 2 \text{ Mn}^{2+}(aq) + 5 \text{ I}_2(aq) + 8 \text{ H}_2O(l)$$

- A 5 B 8 C 10 D 16
- 7. Gas X dissociates on heating to set up the following equilibrium:

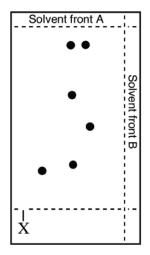
$$X(g) \rightleftharpoons Y(g) + Z(g)$$

A quantity of gas **X** was heated at a constant pressure, *p*, at a certain temperature. The equilibrium partial pressure of **X** was found to be 1/7 p. What is the equilibrium constant, K_p , at this temperature?

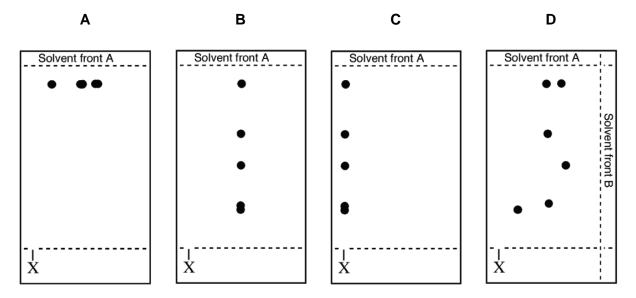
- **A** ${}^{6}/_{7} p$ **B** ${}^{9}/_{7} p$
- С 6*р* **D** 9*р*

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?



9. A hypergolic fuel system consisting of monomethylhydrazine, CH₃NHNH₂, and dinitrogen tetroxide, N₂O₄, (both liquids) is commonly used to propel space vehicles. The two reactants are combined stoichiometrically so that CO₂, H₂O and N₂ are the only products formed (all gases under the same reaction conditions). How many moles of gas are produced from 100 mol of CH₃NHNH₂?

Α	125	В	225
С	400	D	625

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

 $H_2O(I) \rightleftharpoons H^+(aq) + OH^-(aq)$

The equilibrium constant for the reaction is:

 1.0×10^{-14} at 25°C and 5.5×10^{-13} at 100°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?

Α	Mn ₂ O ₇	В	Mn(CH ₃ COO) ₂ ·4H ₂ O
С	KMnO₄	D	MnO₂F

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 $\Delta H_f^\circ = 0$ kJ mol⁻¹?

Α	H ₂ O(I)	В	Na(s)
С	CO ₂ (g)	D	O ₃ (g)

13. A Chemist requires 16.0 mol of liquid ethanol, C₂H₅OH, for a chemical reaction. What volume of ethanol should she use? The density of ethanol is 0.789 g cm⁻³.

Α	0.581 dm ³	В	0.690 dm ³
С	0.934 dm ³	D	1.88 dm ³

14. 2,4,6-trinitrotoluene (TNT, C₇H₅N₃O₆) 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
 CH₃OCH₃
 B
 HI

 C
 CH₃OH
 D
 CH₄
- **17.** The most common batteries used in cars are lead-acid batteries that can be discharged and recharged according to the following equation:

$$Pb(s) + PbO_2(s) + 2 H_2SO_4(aq) \stackrel{discharge}{\underset{recharge}{\leftarrow}} 2 PbSO_4(aq) + 2 H_2O(l)$$

When discharging, which species is the reducing agent?

- A
 Pb(s)
 B
 PbO₂(s)

 C
 SO₄²⁻(aq)
 D
 PbSO₄(aq)
- **18.** By referring to the standard reduction potentials below, which one of the species listed is the best oxidising agent?

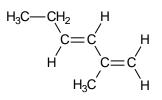
Cd(s) Fe ²⁺ (aq)	B Cu ²⁺ (aq) D Ni(s)
	$Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s) E^{\circ} = -0.44 V$
	$Cd^{2+}(aq) + 2e^{-} \rightleftharpoons Cd(s) E^{\circ} = -0.40 V$
	Ni ²⁺ (aq) + 2 e^{-} \rightleftharpoons Ni(s) E° = −0.23 V
	$Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s) E^{\circ} = +0.34 V$

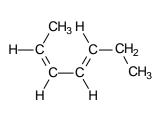
19. Which one of the following species does **not** have eight valence electrons surrounding the central atom?

Α	CCI ₄	В	NH_4^+
~	~ -	_	D O I

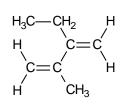
C OF₂ **D** BCl₃

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



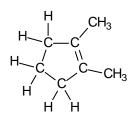


Α

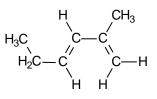


В









The Periodic Table of the Elements

								G	Group								
-	=												N	>	N	IIA	0
							1 H hydrogen										4 He helium 2
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 10
23 Na sodium	24 Mg nagnesium 12											27 Al aluminium 13	28 Si 14	31 P phosphorus 15	32 S sultur	35.5 C1 chlorine 17	40 Ar argon
39 K potassium 19	40 Ca calcium 20	45 Sc scandium t 21 2	48 Ti titanium 22	51 V vanadium 23	-	52 55 Cr Mn chromium manganese 24 25	56 Fe iron 26	59 Co cobatt 27	59 Ni 28 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		84 Kr krypton 36
85 Rb rubidium 37	88 Sr strontium 38	89 trium	91 Zr onium	93 Nb niobium 41	96 Mo molybdenu m			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 53	131 Xe 54
133 Cs caesium 55	137 Ba ^{barium} 56	139 La lanthanum 57 * 7	178 Hf hafnium 72	181 Ta tantalum 73	184 W tungsten 74	186 Re rhenium 75	190 OS osmium 76	192 Ir iridium 77	195 Pt 78	197 Au ^{gold} 79	201 Hg mercury 80	204 T <i>l</i> thallium 81	207 Pb lead 82	209 Bi bismuth 83	PO PO 84	- At astatine 85	- Rn radon 86
- Fr francium 87 *58-71 +90-100	Fr Fr Ra Ac francium radium actinium 87 88 71 Lanthanoid series	Ac Ac 89 † id series series															
				140 Ce cerium 58	141 Pr praseodymium 59	Pr Nd Pm Pr Nd Pm preseodymium neodymium promethium 59 60 61	– Pm promethium 61	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 Iutetium 71
Key b	a a = re X = at b = pr	a = relative atomic mass X = atomic symbol b = proton (atomic) number		232 Th thorium 90	– Pa protactinium 91	238 U uranium 92	- Np 93	– Pu plutonium 94	– Am americium 95	Cm curtum 96	– BK berkelium 97	- Cf califomium 98	Cf ES califomium einsteinium 98	– Fm fermium 100	– Md mendelevium 101	- No nobelium 102	- Lr lawrencium 103

7

Answers

1.	Α	
2.	В	
3.	В	
4.	В	
5.	D	
6.	С	
7.	В	
8.	С	
9.	D	
		$4CH_3NHNH_2(g) + 5N_2O_4(g) \rightarrow 4CO_2(g) + 12H_2O(g) + 9N_2(g)$
10.	Α	
11.	В	
12.	В	
13.	С	
14.	D	
15.	С	
16.	С	
17.	Α	
18.	В	
19.	D	
20.	D	

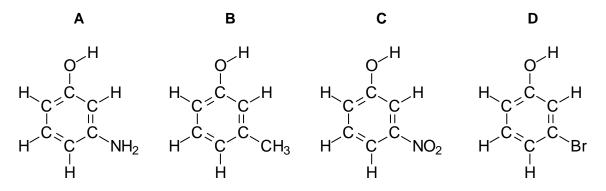
NANYANG			Name: ()
Contraction of the second	a popolo	Chem!stry	Class:	
· · · · · · · · · · · · · · · · · · ·	agage		Date: / /	

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?
 - $\textbf{A} \quad Mg^{2+} < S^{2-} < Cl^- < K^+ < Ca^{2+}$
 - ${\bm B} ~~Mg^{2+} < Ca^{2+} < K^+ < Cl^- < S^{2-}$
 - $\label{eq:constraint} \bm{C} ~~ S^{2-} < C I^- < K^+ < M g^{2+} < C a^{2+}$
 - $\mathbf{D} \quad S^{2-} < Mg^{2+} < Ca^{2+} < Cl^{-} < K^{+}$
- 2. Which one of the following compounds could **not** be obtained by oxidising phosphorus trifluoride, PF₃?

Α	$Na_4P_2O_7 \cdot 10H_2O$	В	$H_4P_2O_6$
С	(NH ₄) ₂ HPO ₃ ·H ₂ O	D	Ca ₅ (PO ₄) ₃ 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

5. What is the enthalpy change for the complete combustion of one mole of liquid isopropanol (molecular formula C₃H₈O)?

	$3 C(s) + 4 H_2(g) + \frac{1}{2} O_2(g)$	$\rightarrow C_3H_8O(I)$	$\Delta H_{\rm f} = -318 \text{ kJ mol}^{-1}$
	$C(s) \ + \ O_2(g) \ \rightarrow \ C$	O ₂ (g)	$\Delta H_{\rm f}$ = -394 kJ mol ⁻¹
	$H_2(g) \ + \ {}^1\!/_2 \ O_2(g) \ \rightarrow \ $	H ₂ O(I)	$\Delta H_{\rm f} = -286 \text{ kJ mol}^{-1}$
Α	–362 kJ	B –998 k.	J
С	–2008 kJ	D –2116	kJ

6. Sodium metal is produced industrially by the electrolysis of molten NaCl, while steel is produced by CO reduction of ores containing Fe(III) in a blast furnace. Tantalum is another useful metal, often used surgically to repair bone because of its high resistance to corrosion. Which one of the following methods could be used industrially to produce tantalum from naturally occurring Ta(V) ores?

Na⁺(aq) + <i>e</i> ⁻ ⇄ Na(s)	$E^{\circ} = -2.71 \text{ V}$
$Fe^{3+}(aq) + 3e^{-} \rightleftharpoons Fe(s)$	$E^{\circ} = +0.82 \text{ V}$
$Ta_2O_5(s) + 10 H^+(aq) + 10 e^- \rightleftharpoons 2 Ta(s) + 5 H_2O(l)$	$E^{\circ} = -0.75 \text{ V}$
$CO_2(g) + 2 H^+(aq) + 2 e^- \rightleftharpoons CO(g) + H_2O(I)$	$E^{\circ} = -0.10 \text{ V}$

- A Either reduction with sodium metal or reduction in a blast furnace.
- **B** Either electrolysis or reduction with sodium metal.
- **C** Electrolysis only.
- **D** Reduction in a blast furnace only.
- 7. What is the oxidation state of molybdenum in the ion $[Mn_2O_4(NCS)_6]^{4-2}$?

Α	+3	В	+4
С	+5	С	+6

- **8.** Which of the following groups of ions can co-exist in significant quantities in aqueous solution without reacting with each other?
 - A Na⁺, Cl⁻, K⁺, OH⁻
 - $\textbf{B} \quad Ag^{+}, NO_{3}^{-}, Na^{+}, Cl^{-}$
 - $\pmb{C} \quad Cu^{2+},\,SO_4{}^{2-},\,Zn^{2+},\,OH^-$
 - **D** Pb²⁺, NO₃⁻, K⁺, I⁻

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

$Cd^{2+}(aq) + 2 e^{-} \rightarrow Cd(s)$	$E^\circ = -0.40 \text{ V}$
$Zn^{2+}(aq) + 2 e^{-} \rightarrow Zn(s)$	$E^\circ = -0.76 \text{ V}$
Ni ²⁺ (aq) + 2 $e^- \rightarrow$ Ni(s)	$E^{\circ} = -0.23 \text{ V}$

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:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) + heat$$

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	Р	С	S	Ν	CI
	Electronegativity	2.19	2.55	2.58	3.04	3.16
Α	P–S		B S–N			
С	S–CI		D C–C			

- **13.** The enthalpy change of which reaction corresponds to ΔH°_{f} for Na₂CO₃(s) at 298 K?

 - **B** Na₂O(s) + CO₂(g) \rightarrow Na₂CO₃(s)
 - **C** 2 Na⁺(aq) + CO₃^{2–}(aq) \rightarrow Na₂CO₃(s)
 - **D** 2 Na⁺(aq) + 2 OH⁻(aq) + CO₂(g) \rightarrow Na₂CO₃(s) + H₂O(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

Α	22 g mol ⁻¹	В	38 g mol ⁻¹
С	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:

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

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?

$$\mathbf{A} \quad 2 \ \mathsf{H}_2\mathsf{O}(\mathsf{I}) \ \rightarrow \ 2 \ \mathsf{H}_2(\mathsf{g}) \ \rightarrow \ \mathsf{O}_2(\mathsf{g})$$

- $\mathbf{B} \quad 2 \text{ NO}(g) \rightarrow \text{ N}_2(g) + \text{ O}_2(g)$
- $\label{eq:constraint} \begin{array}{ccc} C(s) \ + \ O_2(g) \ \rightarrow \ CO_2(g) \end{array}$
- $\label{eq:def_def_def} \begin{array}{rcl} \textbf{D} & H_2(g) \ + \ Cl_2(g) \ \rightarrow \ 2 \ HCl(g) \end{array}$

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, F₂, Cl₂, Br₂ and I₂, 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

								Gn	Group								
	I											III	N	Λ	N	VII	0
							- I	12									4 He
							hydrogen 1										helium 2
7	6	[11	12	14	16	19	20
C	Be											В	U	z	0	ш	Ne
lithium 3	beryllium 4											5 boron	carbon 6	nitrogen 7	oxygen 8	fluorine 9	10
23	24	T										27	28	31	32	35.5	40
Na	Mg											AI	Si	Р			Ar
sodium 11	magnesium 12	F										aluminium 13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
39	40	45	48	51	52	55	56	59	59	29	65	20	73	75			84
¥			F	>		Mn	Fe	ပိ	ïz	Cu	Zn		Ge		Se	Br	Kr
potassium	calcium	scandium	titanium	vanadium		chromium manganese	00	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton
10	70 VU	00	10	50	74	07	20	1001	207	200	20		70	3	5	201	201
22	8 6	80 >	1.6	PIP PIP	06 06	I F		103	001	80L	711	CLL	EL S	122	128	121	131
	ō	1	1	ON .	DIVI O		_	Ē		DY.	3	H	5	00	D -	-	PC
37	strontium 38	39	Zirconium 40	41	molybdenu m 47	technetium 43	ruthenium 44	45	palladium 46	silver 47	cadmium 48	49	50 tin	antimony 51	tellunum 52	53	54 xenon
133	137	139	178	181	184	186	190	192	195	197	201	204	207	209	1	1	1
Cs	Ba	La	Ŧ	Ta	M	Re	Os	Ir		Au	Ρđ	Τl	Pb	Bi	Po	At	Rn
caesium 55	barium 56	57 * 7	hafnium 72	tantalum 73	tungsten 74	rhenium 75	osmium 76	iridium 77	platinum 78	plog 79	mercury 80	thallium 81	lead 82	bismuth 83	polonium 84	astatine 85	radon 86
1	1	1			Ċ,			2						e,			1
Ŀ	Ra	Ac															
francium 87	88	actinium 89 †															
*58-71 L	anthano	*58-71 Lanthanoid series															
190-103	†90-103 Actinoid series	l series															
			6	140	141	144	I	150	152	157	159	162	165	167	169	173	175
				Ce	۲.	PN	Pm			Gd	Tb	D	P	ш		γb	Lu
				cerium 58	59 59	neodymium 60	59 60 61 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70	Iutetium 71
Key a		a = relative atomic mass	mass	232	1	238	1		1	1	1	1		1	1	1	I
×		X = atomic symbol	1000	Ę	Pa		dN	Pu		Ca	BK	പ്	Es		pW	No	
	ot:	b = proton (atomic) number		thorium	protactinium 01	uranium	neptunium	plutonium	americium	curium	berkelium 07	californium	californium einsteinium	100	mendelevium	nobelium	lawrencium 102
2	1			De	10	26	33	5		00	10	20	22	001	101	102	201

Answers

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