General Chemistry Mock Test no. 1

IJSO MCQ mock test
Solutions

Question Number	Option			
1	A	B	C	~~D~~
2	A	B	C	~~D~~
3	A	B	~~C~~	D
4	A	~~B~~	C	D
5	A	B	C	~~D~~
6	~~A~~	B	C	D
7	A	B	C	~~D~~
8	A	B	~~C~~	D
9	~~A~~	B	C	D
10	A	B	~~C~~	D
11	A	B	C	~~D~~
12	A	~~B~~	C	D
13	A	~~B~~	C	D
14	A	B	~~C~~	D
15	A	~~B~~	C	D

Question Number	Option			
16	~~A~~	B	C	D
17	A	~~B~~	C	D
18	A	B	~~C~~	D
19	A	B	C	~~D~~
20	A	B	C	~~D~~
21	~~A~~	B	C	D
22	~~A~~	B	C	D
23	A	B	C	~~D~~
24	A	B	~~C~~	D
25	~~A~~	B	C	D
26	A	~~B~~	C	D
27	A	B	~~C~~	D
28	~~A~~	B	C	D
29	A	~~B~~	C	D
30	~~A~~	B	C	D

Question 1 – Suberic Acid

Let's first calculate the number of moles of NaOH used during the titration:

$$n_{NaOH} = 0.5\frac{mol}{L} \times 23 \times 10^{-13}L = 1.15 \times 10^{-2}mol$$

Because there are two acidic protons on a suberic acid molecule, the amount of moles of NaOH required to neutralize the solution is twice the number of moles of suberic acid:

$$n_{acid} = 5.75 \times 10^{-3}mol$$

Since the sample weighs 1g, the molar mass must be:

$$\mu = \frac{1}{5.75\times10^{-3}} = 173.91\frac{g}{mol}$$

Looking at the general formula:

$$90.02 + 14.02n = 173.91 \Rightarrow n = 6$$

Adding the two carbon atoms from the -COOH groups, 6 + 2 = 8 carbon atoms.

So, the correct answer is **D**.

Question 2 – An acid-base titration

The dissociation reaction of the acid is:

$HA \rightleftharpoons H^+ + A^-$

The acidity constant is given by:

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

We know $[H^+] = 10^{-pH} = 1 \times 10^{-5}$

At half-equivalence, half of the acid was titrated, so $[HA] = [A^-]$, so the acidity constant becomes just $K_a = [H^+] = 1 \times 10^{-5}$

So, the correct answer is **D**

Question 3 – Super-heavy elements

A. Incorrect, the 8th electron shell would in fact be occupied by electrons, however, the number of electrons this shell can occupy would be:
   2+6+10+14+18+22+26+30 = 128

   Which would come from subshells s, p, d, f, g, h, i and j, respectively.

   The formula $2n^2 = 2 \times 8^2 = 128$ can also be used.

B. Incorrect, From Aufbau's principle, the distribution would actually be:
   [Og]$8s^2 5g^1$

C. Correct, the subshells f, g and h of the sixth layer have no electrons, only the subshells s, p and d are actually full.

D. Incorrect, only the subshells s and p of the seventh layer are fully occupied. The subshells d, f, g, h and i are empty.

So, the correct answer is **C**.

Question 4 – Kinetics of an unusual reaction

$\Delta(pH) = 3-1 = 2$

So

$[H_3O^+]$ in the beginning = 10^{-3}

$[H_3O^+]$ in the end = 10^{-1}

Also it is true that:

$$v_2 = 100v_1$$

$$(10^{-1})^x = 10^2(10^{-3})^x$$

$$10^{-x} = 10^{2-3x}$$

$$-x + 3x = 2$$

$$2x = 2$$

$$x = 1$$

So, the current answer is **B**

Question 5 – Hydrogen iodide decomposition

Let n be the number of moles of hydrogen iodide initially in the container. After equilibrium is established, the number of moles of hydrogen iodide will be n(1-α).

From the stoichiometry of the reaction, if αn moles of HI decompose, αn/2 moles of H_2 and αn/2 moles of I_2 will form.

Because 2 moles of gas form 2 moles of gas, when writing the equilibrium constant, the volume in the expressions of the concentrations cancel out and we only need the number of moles.

We can write $Kc = \frac{\frac{1}{4}(n\alpha)^2}{(n(1-\alpha))^2}$

Taking the square root of this equation and solving for α, we get the final required formula, $\alpha = \frac{2\sqrt{K_c}}{1+2\sqrt{K_c}}$

The correct answer is **D**

Question 6 – Accident at Willy Wonka's factory

From the ideal gas law, we know that the number of moles is directly proportional to the volume (in the case of identical pressures and temperatures). So, initially, there are n moles of ammonia and 2n moles of hydrochloric acid. The reaction taking place is $HCl + NH_3 \rightarrow NH_4Cl$. Because NH_4Cl is an ionic substance, it's a solid. Ammonia is the limiting reagent and is consumed entirely. The only amount of gas remaining are n moles of HCl.

Initially there were 3n moles of gas (2n HCl + n NH_3), and the pressure was 1atm. Now that the number of moles of gas is n (and the total volume and temperature are the same), we can say the final pressure is $1\text{atm} \cdot \frac{n}{3n} = 0.33\text{atm}$, which corresponds to answer option **A**.

Question 7 – Latimer Diagrams

Let's analyze each of the given reactions:

A. Molecular chlorine Cl_2 is getting both reduced and oxidized, as it is the only chlorine containing reactant. It is being oxidized to chlorate ions (-1.47V) and reduced to chloride ions (+1.36V). The overall cell potential is $1.36\text{V} - 1.47\text{V} = -0.11\text{V} < 0$, so the reaction is not spontaneous

B. In this reaction, chromate is being reduced to Cr(III) (+1.38V), while chlorine is oxidized to hypochlorite (-1.63V). The cell potential is $1.38\text{V} - 1.63\text{V} = -0.25\text{V} < 0$, so the reaction is not spontaneous

C. The only chlorine containing product is the hypochlorite ion (even if it is found as a fixture of hypochlorous acid and potassium hypochlorite, from a redox point of view there's no difference). So, chlorate is being reduced to hypochlorite (+1.43V), while chlorine is being oxidized to hypochlorite (-1.63V). The cell potential is $1.43V - 1.63V = -0.20V < 0$, so this reaction is not spontaneous either.

D. In this last reaction, chromium (III) is oxidized to chromate (-1.38V), while perchlorate is reduced to chlorine (+1.39V). The cell potential is $1.39V - 1.38V = 0.01V > 0$, so this reaction is spontaneous in standard conditions.

All potentials were taken from the Latimer diagrams (potentials of reactions inverse to those in the diagrams are the opposite of the given potentials).

The only spontaneous reaction is answer option **D**.

Question 8 – Boling points of some usual compounds

Out of the given substances, calcium carbonate is the only ionic one. Ionic substances have the highest boiling points as they are stabilized by very strong electrostatic interactions.

The next interactions in strength are hydrogen bonds. Out of the substances given, water is the only one that can form hydrogen bonds. Hydrochloric acid follows water, with strong dipole-dipole forces. Its boiling point is lower than that of the water because chlorine is not electronegative enough to form hydrogen bonds.

For the two left molecules, nitrogen and carbon dioxide, we can't make an argument based on strong intermolecular forces. However, carbon dioxide is a larger molecule, with more electrons, higher polarizability and stronger inductive forces. So CO_2 has a higher boiling point than N_2.

Finally, the order is $N_2 < CO_2 < HCl < H_2O < CaCO_3$

Answer **C**

Question 9 – Some chemical reactions

The main substance which gives stomach acid its acidity is HCl, so C = HCl. The yellow simple substance (matching F's description) is sulfur, so F = S.

D is analogous to C, so another haloacid, D = HX.

Let's look at reaction (1): the two water molecules (reactants) contain 4 hydrogen atoms, which will be then be found in C and D respectively. That leaves 2 oxygen atoms, for substance B. Since we are told B contains sulfur (substance F), we can deduce that B is sulfur dioxide $\mathrm{B = SO_2}$.

Reaction (2) becomes $\mathrm{SO_2 + 2E \rightarrow 3S + 2H_2O}$, from which it can be easily deduced that $\mathrm{E = H_2S}$. Using this in reaction (3), $\mathrm{G = Na_2S}$.

Reaction (4) is $\mathrm{3S + 5NaOH \rightarrow 2Na_2S + H + 2H_2O}$. Conservation of number of atoms gives $\mathrm{H = NaHSO_3}$.

Now that we've deciphered all substances, we can analyze the given reactions:

A. $\mathrm{Na_2S + NaOH}$ – sodium sulfide is a basic salt, as it has no acidic proton, so it doesn't react with sodium hydroxide – reaction not possible
B. $\mathrm{NaHSO_3 + NaOH}$ – can take place, according to $\mathrm{NaHSO_3 + NaOH \rightarrow Na_2SO_3 + H_2O}$, because sodium bisulfite has an acidic proton which can react with sodium hydroxide
C. $SO_2 + NaOH$ – sulfur dioxide and can react with sodium hydroxide – reaction can't be written exactly; depending on the stoichiometry, different quantities of sodium sulfite (Na_2SO_3) and sodium bisulfite ($NaHSO_3$) are formed, but, regardless of this, a reaction does take place
D. $\mathrm{HX + Na_2S}$ – since sodium sulfide is basic, a reaction can take place, in which the sulfide ion is partly protonated, $\mathrm{HX + Na_2S \rightleftharpoons NaHS + NaX}$

So, the impossible reaction is option **A**.

Question 10 – Acidity of hydrogen selenide and telluride

Let's analyze the first equilibrium:

$$HTe^- + HSe^- \rightleftharpoons H_2Te + Se^{2-}$$

It's the protonation of HTe^- by HSe^-. If the equilibrium is shifted to the left, the reaction is not favoured, so HSe^- does not protonate HTe^-. That is, HSe^- does not protonate the conjugate base of H_2Te in large amounts, so HSe^- is a weaker acid than H_2Te.

Let's now look at the second equilibrium:

$$HTe^- + Se^{2-} \rightleftharpoons HSe^- + Te^{2-}$$

This is the protonation of Se^{2-} by HTe^-, shifted to the left so unfavoured. In this case, HTe^- does not protonate the conjugate base of HSe^- in large amounts, so HSe^- is stronger than HTe^-.

Finally, we can order them, from strongest to weakest, $H_2Te > HSe^- > HTe^-$

Correct answer **C**

Question 11 – A puzzle about atoms

The most stable form of oxygen is ^{16}O, which has 8 neutrons. That means, B has 9 neutrons. Let x be the number of protons in B.

Since B and C are isotopes, they have the same number of protons, so C has x protons.

The mass number of B is (8+x), equal to that of A. Since A's mass number is larger than C's mass number by one unit, C has mass number (7+x).

Using C's mass number of (7+x) and knowing it has x protons, we can calculate that it has 7 neutrons.

A has the same number of neutrons as C, so 7. The element which has 7 neutrons in its most stable form is nitrogen (in the form of ^{14}N).

So, the correct answer is **D**

Question 12 – A quantitative analysis

$$FeCl_3 + 3\ AgNO_3 \rightarrow 3\ AgCl + Fe(NO_3)_3$$

$$FeCl_2 + 2\ AgNO_3 \rightarrow 2\ AgCl + Fe(NO_3)_2$$

Total amount of silver chloride formed = 4.87 g

$$\text{Moles} = \frac{\text{Mass}}{\text{Molar Mass}} = \frac{4.87}{107.87 + 35.45} = \frac{4.87}{143.32} = 0.03398\ \text{mol}$$

If the moles of $FeCl_3$ is x and the moles of $FeCl_2$ is y, then 3x + 2y = 0.03398.

The magnesium reacts with Fe^{2+} and Fe^{3+} in the following ways

$$2\ Fe^{3+} + 3\ Mg \rightarrow 2\ Fe + 3\ Mg^{2+}$$

$$Fe^{2+} + Mg \rightarrow Fe + Mg^{2+}$$

Total Mg moles reacted = 1.5 x + y

Toal Fe moles reacted = x + y

Change in mass = 55.85 (x + y) – $24.31(1.5x + y) = 19.385x + 31.54y$

$$19.385x + 31.54y = 0.313$$

Mutiplying the first equation by 15.77, we get

47.31 x + 31.54 y = 0.5359

From this, we get $x = 7.981 \times 10^{-3}$ moles

$y = 5.019 \times 10^{-3}$ moles.

Mass of $FeCl_3$ = $7.981 \times 10^{-3} \times (55.85 + 35.45 \times 3) = 1.295$ g

Mass of $FeCl_2$ = $5.019 \times 10^{-3} \times (55.85 + 35.45 \times 2) = 0.6362$ g

Total mass of the solution = $100\ \text{mL} \times 1\ \text{g/mL} = 100\ \text{g}$

Percentage concentration of $FeCl_3 = \frac{1.295\ g}{100\ g} \times 100\% = 1.295\ \%$

Percentage concentration of $FeCl_2 = \frac{0.6362\ g}{100\ g} \times 100\% = 0.6362\%$

Correct answer – **B**

Question 13 – Thermochemistry of neutralization

$n_{HCl} = c_{M\,HCl} \cdot V_{s\,HCl} = 2 \cdot 50/1000 = 0.1$ moles HCl

$n_{NaOH} = c_{M\,NaOH} \cdot V_{s\,NaOH} = 1 \cdot 50/1000 = 0.05$ moles NaOH

The reaction is: $HCl + NaOH \rightarrow NaCl + H_2O$

We have an excess of HCl, only 0.05 moles of each substance will react.

The change in temperature is: $\Delta t = 31.8°C - 25°C = 6.8°C$

The solution's mass after mixing is: $m_s = (V_{s\,HCl} + V_{s\,NaOH}) \times \rho = 100g$

The heat necessary to warm the solution accordingly is: $Q = m_s \cdot c \cdot \Delta t = 100 \cdot 4.18 \cdot 6.8 = 2842.4$ J

This heat is released by the neutralisation of 0.05 moles of HCl. Keep in mind that one mole of HCl corresponds to one mole of H_2O. Therefore, the enthalpy per one mole of water formed it will be: $\Delta H = -Q = -2842.4/0.05 = 56800$ J/mol $= -56.8$ kJ/mol which corresponds to answer **B**.

Question 14 – Electrochemical cell

In order to check in which way the total reaction is directed, we need to calculate E for both cases:

Firstly: Zn is the cathode and Cu is the anode.

$E = E_{cat} - E_{an} = -0.76 - 0.34 = -1.1 \text{ V} < 0$ which means the reaction is not spontaneous in this direction.

Let's try it the other way around: Cu is the cathode and Zn is the anode.

$E = E_{cat} - E_{an} = 0.34 - (-0.76) = +1{,}1 \text{ V} > 0$ which means the reaction is spontaneous and will take place.

The total reaction is: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

Now that we have established this, let's take a look at the answer options:

A. Answer A is incorrect because electrons flow from the anode to the cathode, therefore from Zn to Cu, not the other way around.
B. Answer B is incorrect, because Zn, undergoing oxidation, is the anode, not the cathode.
C. Answer C is **correct**, as copper, being the cathode, undergoes reduction, and we have calculated the cell's potential, 1.1V.
D. Answer D is incorrect, as electrons pass through the outside circuit, not through the salt bridge (ions pass through the salt bridge to maintain neutrality).

So, the correct answer is **C**

Question 15 – The antiacid tablet

$$NaHCO_3 + HCl \rightarrow NaCl + CO_2 + H_2O$$

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

pH of the solution = 4.16

$$pH = -\log [H^+] = 4.16$$

$$[H^+] = 10^{-4.16} = 6.918 \times 10^{-5}$$

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightleftharpoons H^+ + HCO_3{}^-$$

The dissociation of H_2CO_3 is partial and has a Ka of 4.3×10^{-7}

Ka = $\frac{[H^+][HCO_3{}^-]}{[H_2CO_3]} = 4.3 \times 10^{-7}$

$$[H^+] = [HCO_3{}^-] = 6.918 \times 10^{-5}$$

$$[H_2CO_3] = \frac{(6.918 \times 10^{-5})^2}{4.3 \times 10^{-7}} = 0.01113\ M \gg [HCO_3^-]$$

CO_2 Moles = Concentration x Volume = 0.01113 M x 1L = 0.01113 moles.

$NaHCO_3$ moles = $\frac{x}{MM\ (NaHCO_3)} = \frac{x}{84}$

$CaCO_3$ moles = $\frac{1-x}{MM\ (CaCO_3)} = \frac{1-x}{100}$

$$\frac{x}{84} + \frac{1-x}{100} = 0.01113$$

$$x = 0.5937\ g$$

Mass of $CaCO_3$ = $1 - 0.5937\ g = 0.4063\ g$

Percentage = 40.63%

So, the correct answer is **B**

Question 16 – Unusual data about acetic acid

The acidity constant of acetic acid in water is $K_a = 10^{-pKa} = 1.78 \cdot 10^{-5}$.

The concentration of pure acetic acid is $c = \frac{n}{V} = \frac{m/\mu}{m/\rho} = \frac{\rho}{\mu} = 17.5M$.

The equilibrium constant of the auto-protolysis reaction $2HA \rightleftharpoons A^- + H_2A^+$ then becomes $K = \frac{[A^-][H_2A^+]}{[HA]^2} = \frac{10^{-14}}{17.5^2} = 3.26 \cdot 10^{-17}$

To find the pKb of acetic acid, we want to find the equilibrium constant of the chemical reaction $HA + H_2O \rightleftharpoons H_2A^+ + HO^-$.

Similar to Hess's law, we can get to this reaction after the following cycle:

(1) $2HA \rightleftharpoons A^- + H_2A^+$ (K)

(2) $A^- + H_3O^+ \rightleftharpoons HA + H_2O$ ($\frac{1}{K_a}$)

(3) $2H_2O \rightleftharpoons H_3O^+ + HO^-$ (K_w)

The net reaction is $HA + H_2O \rightleftharpoons H_2A^+ + HO^-$, so, similar to Hess's law, we can say that $K_b = \frac{KK_w}{K_a}$.

This result can also be obtained through calculations only:

$$K_b = \frac{[H_2A^+][HO^-]}{[HA]} = \frac{\frac{K[HA]^2}{[A^-]} \cdot \frac{K_w}{[H_3O^+]}}{[HA]} = \frac{KK_w[HA]^2}{[HA]([A^-] \cdot [H_3O^+])} = \frac{KK_w[HA]^2}{[HA]K_a[HA]} = \frac{KK_w}{K_a}$$

Numerically, $K_b = 1.86 \cdot 10^{-26}$, so pKb = $-\log K_b = 25.74$

Finally, the correct answer is **A**.

Question 17 – Sulfur Dioxide Oxidation

At both t = 20min and t = 30min, the system seems to have settled into an equilibrium position which, after the change, shifts. Also, there is a sudden change in the concentration of different substances, indicating their addition. Catalysts do not influence the equilibrium position so it wasn't added at these two moments.

At t = 10min, the reaction rate (and the reaction order) seems to change, which is a strong indicator of a catalyst being added.

At t = 0min, the reaction just starts, with a relatively low rate compared to the following time intervals. This indicates an uncatalyzed reaction

So, the most likely time at which the catalyst was added is t = 10min (answer **B**).

Question 18 – Investigating Kinetics

When concentration of A was doubled, the rate of the reaction was 16 times. So, the rate of the reaction is dependent on A to the power of 4.

When the concentration of B was tripled, the rate of the reaction was $\sqrt{3}$ times. So, the rate of the reaction is dependent on B to the power of 0.5.

Rate of the reaction = $k\,[A]^4[B]^{0.5}$

Substituting to the first set of values, you get

$1.00 \times 10^{-5} = k\,[0.2]^4\,[0.3]^{0.5} = 8.764 \times 10^{-4}\,k$

$k = 0.01141$

Now, to find the units of k, it is just a simple unit analysis.

Rate of the reaction units = $\text{mol} / \text{L} \cdot \text{min}$

Concentration of a reactant = mol / L

Units of k = $\dfrac{\text{mol} / \text{L} \cdot \text{min}}{(\text{mol} / \text{L})^{4.5}} = \dfrac{\text{L}^{3.5}}{\text{mol}^{3.5} \cdot \text{min}}$

The answer choice that matches the units and the numerical value is **C**.

Question 19 – Preparation of sulfuric acid

250 g oleum contains: $80/100 \cdot 250 = 200\text{g } H_2SO_4$ and $20/100 \cdot 250 = 50\text{g } SO_3$

Let x be the mass of water added to the oleum, in grams.

Upon the addition of water, we will have the following reaction:

$SO_3 + H_2O \rightarrow H_2SO_4$

80g SO_3 will form 98g H_2SO_4

50g SO_3 will form y g H_2SO_4

y=50 · 98/80 = 61.25g H_2SO_4

The final solution will have a concentration of 80%. The total mass of H_2SO_4 will be 200 + 61.25 = 261.25g. The solution's total mass will be 250+x.

$\frac{80}{100} = \frac{261.25}{250+x}$

250+x = 326.56

x = 76.56g water need to be added

So, the correct answer is **D**

Question 20 – Finding composition of a mixture

The molar masses of sodium carbonate and sodium bicarbonate are 105.99g/mol and 84g/mol respectively. Let p be the mass percent of sodium carbonate in the original mixture.

The mass of sodium carbonate is $4p$, while the mass of sodium bicarbonate is $4(1 - p)$.

The number of moles of carbon dioxide is $\frac{1.76}{44} = 0.04\text{mol}$.

From the stoichiometries of the two reactions, the number of moles of carbon dioxide is $\frac{4p}{105.99} + \frac{4(1-p)}{84} = 0.04$. Solving for p, we get $p = 0.7709 = 77.09\%$

So, the correct answer is **D**

Question 21 – An interesting reaction

The only metal with 3d electrons involved in these reactions is Cr, so C contains Cr. We know one of the by-products of this reaction will be potassium sulfate. Since there are 4 potassium atoms in the reactants, two sulfate groups will be found in the products in the form of potassium sulfate, and potassium sulfate will have a coefficient of 2. Since C contains Cr, we can say B = K_2SO_4

To account for the 6 sulfate groups and 4 Cr atoms remaining, substance C is mostly likely Cr (III) sulfate, so C = $Cr_2(SO_4)_3$

From the conservation of the number of atoms for each element, we can find that A contains 3 carbon atoms, 6 hydrogen atoms and one oxygen atom, so A = C_3H_6O

So, the correct answer is **A**

Question 22 – Halide geometries

A. Correct, Beryllium has 2 electrons on its outer shell, and each Chlorine atom will bond to one electron. Therefore, there will not be any lone pairs and the geometry will be linear
B. Incorrect, BF_3 has a trigonal planar geometry, because it forms three bonds and has no lone electron pairs. In order to be tetrahedral, the central atom would have to form 4 bonds and have no lone electron pairs.
C. Incorrect, PCl_5 has a Trigonal bipyramidal geometry and does not have any lone electron pairs.
D. Incorrect, SF_6 has an octahedral geometry and sulfur can bond with 6 fluorine atoms, since it has 6 electrons on its outer layer.

So, the correct answer is **A**.

Question 23 – Thermodynamics of hydrogen production

Adding all 3 reactions together gives the following net reaction

$$H_2O \rightarrow \frac{1}{2}O_2 + H_2$$

From Hess' law, the sum $\Delta H_1 + \Delta H_2 + \Delta H_3$, is equal to the change in enthalpy of the net reaction. This corresponds to answer option D.

So, the correct answer is **D**.

Question 24 – Colors of two pH indicators

BG changes its color from yellow to blue, going through green (color intermediate between yellow and blue). Similarly, PR changes from yellow to red, through orange. We can say almost certainly that both indicators have only two forms, a protonated one and a deprotonated one, with the intermediate colors coming from a mixture of the two. Protonated forms are predominant in more acidic mediums, so both protonated forms are yellow. Let's analyze the answer options:

A. The yellow form is the protonated one, so the two have been swapped – BG was deprotonated, while PR is still protonated – the answer option is false
B. Since the basic form of BG is blue, its absorption coefficient is lowest, not highest, at blue wavelengths – it reflects most of the blue light – answer option is false
C. The red deprotonated form of PR can accept a proton to form the yellow protonated form – exactly the definition of a Bronsted base – answer option C is correct
D. As explained before, both indicators most likely are monoprotic acids, containing only one proton which results in two forms. The green color is explained as a mixture of the two – the answer option is false

So, the correct answer is **C**

Question 25 – A thermochemical cycle

1. Formation of CO (g):

$$C_{graph} + \frac{1}{2} O_2 \rightarrow CO \qquad \Delta H = \Delta H_f\,(CO)$$

2. Combustion of C_{graph}:

$$C_{graph} + O_2 \rightarrow CO_2 \qquad \Delta H = \Delta H_c\,(C_{graph})$$

3. Combustion of CO (g):

$$CO + \frac{1}{2} O_2 \rightarrow CO_2 \qquad \Delta H = \Delta H_c\,(CO)$$

Using Hess's law, we can build the formation of CO using 2 and 3.

Equation 2 - Equation 3

$$(C_{graph} + O_2 \rightarrow CO_2) - (CO + \frac{1}{2} O_2 \rightarrow CO_2)$$

Net reaction:

$$C_{graph} + \frac{1}{2} O_2 \rightarrow CO$$

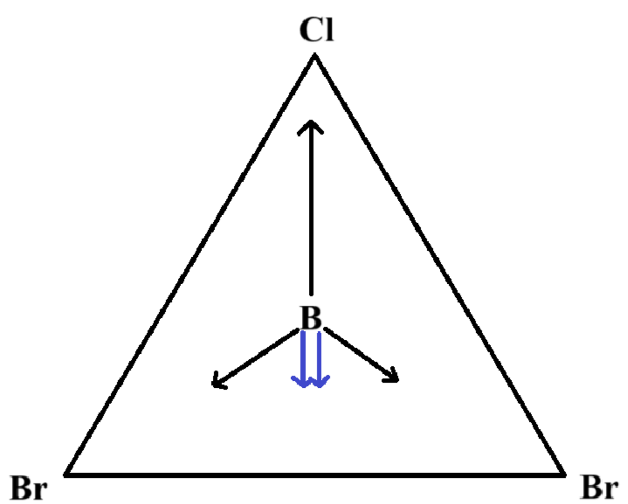
$$\Delta H_f\,(CO) = \Delta H_c\,(C_{graph}) - \Delta H_c\,(CO)$$

So, the correct answer is **A**

Question 26 – Polar molecules

To calculate the net dipole moment, we need to sum the dipole moment vectors associated with each bond. Therefore, we need to project all the vectors on an axis for the ease of calculations. The Oy axis (B-Cl axis) is the easiest to use for calculations, while the Ox components of the B-Br dipole moments cancel out.

$\overrightarrow{\mu_{tot}} = \overrightarrow{\mu_{B-Cl}} + \overrightarrow{\mu_{B-Br,1}} + \overrightarrow{\mu_{B-Br,2}} \Longrightarrow \mu_{tot} = \mu_{B-Cl} - 2\mu_{B-Br} \cdot \sin(30°) =$
$0.75 - 2 \cdot 0.55 \cdot \frac{1}{2} = 0.20D$



So, the correct answer is **B**.

Question 27 – Two equilibrium states

In the first scenario, at equilibrium, the concentrations of the compounds are

$$NO_2 = a \Rightarrow SO_2 = a$$

Hence, $SO_3 = NO = 1 - a$

So, the equilibrium constant $K = \frac{(1-a)^2}{a^2}$

In the second scenario, at equilibrium, the concentrations of the compounds are

$$NO_2 = b \Rightarrow SO_2 = b$$

Hence, $SO_3 = NO = 2 - b$

So, the equilibrium constants $K = \frac{(2-b)^2}{b^2}$

Equaling the two equations, we get $\frac{(1-a)^2}{a^2} = \frac{(2-b)^2}{b^2}$

So, $\frac{1-a}{a} = \frac{2-b}{b}$

$$b - ba = 2a - ba$$

$$b = 2a$$

So, the correct answer is **C**

Question 28 – Finding the formula of a hydrate

Mass of water formed = 1.58 g

Moles of water lost = $\frac{1.58\text{ g}}{18\text{ g/mol}} = 0.08778\text{ mol}$

Since each mole of hydrate loses 4 moles of water:

Total moles of $X \cdot 5H_2O$ = moles of water / 4 = $\frac{0.08778\text{ mol}}{4} = 0.02194\text{ mol}$

$$\text{Molar mass} = \frac{\text{Mass}}{\text{No. of moles}} = \frac{5.50\text{ g}}{0.02194\text{ mol}} = 250.6\text{ g/mol}$$

Molar mass of X = Molar mass of $X \cdot 5H_2O$ - mass of 5 water molecules

= $250.6\text{ g/mol} - 5 \times 18\text{ g/mol} = 160.6\text{ g/mol}$

So, the correct answer is **A** (corresponds to $CuSO_4 \times 5H_2O$)

Question 29 – An unusual battery

Since the reduction potential of silver is larger than that of magnesium, silver is getting reduced and magnesium is getting oxidized. That gives the cell potential:

$E_{cell} = E_{red}(Ag) + E_{ox}(Mg) = E_{red}(Ag) - E_{red}(Mg) = 3.17V$

Oxidation takes place at the anode, so the anode is the magnesium electrode. The corrosion of 10g of magnesium, represents the corrosion of 10/24.3 = 0.412mol of magnesium.

From the stoichiometry of the reaction, this produces $0.412 \cdot 2 = 0.824$mol of electrons, which carry a charge of $0.824 \cdot 96500 = 79516$C

The time is the charge divided by the current, so 79516/10 = 7951.6s $\approx 8 \times 10^3$s

So, the correct answer is **B**

Question 30 – Thermochemical processes

It is clear that the missing energy is the lattice formation energy. There is no such thing as a Na to Cl electron transfer – this electron transfer is given by the Na ionization energy and the Cl electron affinity, without any other additional energy.

Let's write down the known steps

$Na\ (s) \rightarrow Na\ (g)$: $+108.40$ kJ/mol - sublimation

$Na\ (g) \rightarrow Na^+\ (g) + e^-$: $+495.80$ kJ/mol - 1st ionization

$\frac{1}{2}Cl_2\ (g) \rightarrow Cl\ (g)$: $+\ 121.45$ kJ/mol - dissosciation

$Cl\ (g) + e^- \rightarrow Cl^-\ (g)$: $-\ 349.00$ kJ/mol - electron affinity

$U_{latt} = Na^+\ (g) + Cl^-\ (g) \rightarrow NaCl\ (s)$

$\Delta H_f^0\ (NaCl) = -411.20 = 108.40 + 495.80 + 121.45 - 349.00 + U_{latt}$

$U_{latt} = -787.85$ kJ/mol

So, the correct answer is **A**