General Chemistry Mock Test No. 1

IJSO MCQ mock test

This is an IJSO General Chemistry mock test, designed to mimic the style, depth, and difficulty of chemistry questions found in the IJSO. Its aim is to help students strengthen their understanding of the chemistry concepts behind the IJSO and similar competitions.

The questions in this paper were made by the following members of our team (in alphabetical order):

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In solving the questions, you might need to use the following constants:

Constant	Notation	Value
Acceleration due to gravity	g	$9.8\ ms^{-2}$
Gravitational constant	G	$6.67 \cdot 10^{-11}\ m^3/\ kg \cdot s^2$
Planck's constant	h	$6.62 \cdot 10^{-34}\ J \cdot s$
Elementary charge	e	$1.6 \cdot 10^{-19}\ C$
Speed of light in vacuum	c	$3 \cdot 10^8\ ms^{-1}$
Density of water	ρ	$1000\ kg\ m^{-3}$
Stefan-Boltzmann constant	σ	$5.67 \cdot 10^{-8}\ \frac{W}{m^2K^4}$
Universal gas constant	R	$8.314\ J\ mol^{-1}\ K^{-1}$ $0.0821\ atm\ L\ mol^{-1}\ K^{-1}$
Avogadro's number	N_A	$6.022 \cdot 10^{23}\ mol^{-1}$
Faraday's constant	F	$96\ 500\ C/mol$
Pi	π	3.14
Electrical permittivity of free space	ε_0	$8.85 \cdot 10^{-12}\ F \cdot m^{-1}$
Magnetic permeability of free space	μ_0	$4\pi \cdot 10^{-7}\ H/m$
Mass of Earth		$5.97 \cdot 10^{24}\ kg$
Mass of Moon		$7.35 \cdot 10^{22}\ kg$
Mass of Sun		$1.99 \cdot 10^{30}\ kg$
Radius of Earth		$6.4 \cdot 10^6\ km$
Radius of Moon		$1.7 \cdot 10^6\ km$
Radius of Sun		$6.96 \cdot 10^8\ km$
Specific heat capacity of water	c_w	$4200\ J/kg \cdot °C$
Average molar mass of air	M	$28.9\ g/mol$

If any other value is provided in the problem, use the value provided, not the one in the table. You can also use the following conversion formulas:

$T\ (K) = t\ (°C) + 273$	$t\ (°F) = \frac{9}{5} t\ (°C) + 32$
$1bar = 1atm = 101\ 000Pa = 760mmHg$	$1u = 1Da = 1.66 \cdot 10^{-27} kg$
$1L = 10^{-3}\ m^3$	$1\ day = 24h$

If needed, you can use the periodic table given bellow:

(Use atomic masses rounded to two decimal places.)

IUPAC Periodic Table of the Elements

Key: atomic number / **Symbol** / name / abridged standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** hydrogen 1.0080 ± 0.0002																	2 **He** helium 4.0026 ± 0.0001
3 **Li** lithium 6.94 ± 0.06	4 **Be** beryllium 9.0122 ± 0.0001											5 **B** boron 10.81 ± 0.02	6 **C** carbon 12.011 ± 0.002	7 **N** nitrogen 14.007 ± 0.001	8 **O** oxygen 15.999 ± 0.001	9 **F** fluorine 18.998 ± 0.001	10 **Ne** neon 20.180 ± 0.001
11 **Na** sodium 22.990 ± 0.001	12 **Mg** magnesium 24.305 ± 0.002											13 **Al** aluminium 26.982 ± 0.001	14 **Si** silicon 28.085 ± 0.001	15 **P** phosphorus 30.974 ± 0.001	16 **S** sulfur 32.06 ± 0.02	17 **Cl** chlorine 35.45 ± 0.01	18 **Ar** argon 39.95 ± 0.16
19 **K** potassium 39.098 ± 0.001	20 **Ca** calcium 40.078 ± 0.004	21 **Sc** scandium 44.956 ± 0.001	22 **Ti** titanium 47.867 ± 0.001	23 **V** vanadium 50.942 ± 0.001	24 **Cr** chromium 51.996 ± 0.001	25 **Mn** manganese 54.938 ± 0.001	26 **Fe** iron 55.845 ± 0.002	27 **Co** cobalt 58.933 ± 0.001	28 **Ni** nickel 58.693 ± 0.001	29 **Cu** copper 63.546 ± 0.003	30 **Zn** zinc 65.38 ± 0.02	31 **Ga** gallium 69.723 ± 0.001	32 **Ge** germanium 72.630 ± 0.008	33 **As** arsenic 74.922 ± 0.001	34 **Se** selenium 78.971 ± 0.008	35 **Br** bromine 79.904 ± 0.003	36 **Kr** krypton 83.798 ± 0.002
37 **Rb** rubidium 85.468 ± 0.001	38 **Sr** strontium 87.62 ± 0.01	39 **Y** yttrium 88.906 ± 0.001	40 **Zr** zirconium 91.224 ± 0.002	41 **Nb** niobium 92.906 ± 0.001	42 **Mo** molybdenum 95.95 ± 0.01	43 **Tc** technetium [97]	44 **Ru** ruthenium 101.07 ± 0.02	45 **Rh** rhodium 102.91 ± 0.01	46 **Pd** palladium 106.42 ± 0.01	47 **Ag** silver 107.87 ± 0.01	48 **Cd** cadmium 112.41 ± 0.01	49 **In** indium 114.82 ± 0.01	50 **Sn** tin 118.71 ± 0.01	51 **Sb** antimony 121.76 ± 0.01	52 **Te** tellurium 127.60 ± 0.03	53 **I** iodine 126.90 ± 0.01	54 **Xe** xenon 131.29 ± 0.01
55 **Cs** caesium 132.91 ± 0.01	56 **Ba** barium 137.33 ± 0.01	57-71 lanthanoids	72 **Hf** hafnium 178.49 ± 0.01	73 **Ta** tantalum 180.95 ± 0.01	74 **W** tungsten 183.84 ± 0.01	75 **Re** rhenium 186.21 ± 0.01	76 **Os** osmium 190.23 ± 0.03	77 **Ir** iridium 192.22 ± 0.01	78 **Pt** platinum 195.08 ± 0.02	79 **Au** gold 196.97 ± 0.01	80 **Hg** mercury 200.59 ± 0.01	81 **Tl** thallium 204.38 ± 0.01	82 **Pb** lead 207.2 ± 1.1	83 **Bi** bismuth 208.98 ± 0.01	84 **Po** polonium [209]	85 **At** astatine [210]	86 **Rn** radon [222]
87 **Fr** francium [223]	88 **Ra** radium [226]	89-103 actinoids	104 **Rf** rutherfordium [267]	105 **Db** dubnium [268]	106 **Sg** seaborgium [269]	107 **Bh** bohrium [270]	108 **Hs** hassium [269]	109 **Mt** meitnerium [277]	110 **Ds** darmstadtium [281]	111 **Rg** roentgenium [282]	112 **Cn** copernicium [285]	113 **Nh** nihonium [286]	114 **Fl** flerovium [290]	115 **Mc** moscovium [290]	116 **Lv** livermorium [293]	117 **Ts** tennessine [294]	118 **Og** oganesson [294]

57 **La** lanthanum 138.91 ± 0.01	58 **Ce** cerium 140.12 ± 0.01	59 **Pr** praseodymium 140.91 ± 0.01	60 **Nd** neodymium 144.24 ± 0.01	61 **Pm** promethium [145]	62 **Sm** samarium 150.36 ± 0.02	63 **Eu** europium 151.96 ± 0.01	64 **Gd** gadolinium 157.25 ± 0.03	65 **Tb** terbium 158.93 ± 0.01	66 **Dy** dysprosium 162.50 ± 0.01	67 **Ho** holmium 164.93 ± 0.01	68 **Er** erbium 167.26 ± 0.01	69 **Tm** thulium 168.93 ± 0.01	70 **Yb** ytterbium 173.05 ± 0.02	71 **Lu** lutetium 174.97 ± 0.01
89 **Ac** actinium [227]	90 **Th** thorium 232.04 ± 0.01	91 **Pa** protactinium 231.04 ± 0.01	92 **U** uranium 238.03 ± 0.01	93 **Np** neptunium [237]	94 **Pu** plutonium [244]	95 **Am** americium [243]	96 **Cm** curium [247]	97 **Bk** berkelium [247]	98 **Cf** californium [251]	99 **Es** einsteinium [252]	100 **Fm** fermium [257]	101 **Md** mendelevium [258]	102 **No** nobelium [259]	103 **Lr** lawrencium [262]

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For notes and updates to this table, see www.iupac.org. This version is dated 4 May 2022.

Question 1 – Suberic acid

Suberic acid is an organic acid with the formula $HOOC(CH_2)_nCOOH$, where both protons in the COOH groups are acidic.

A sample of suberic acid weighing 1.00g is titrated with 0.5M NaOH solution in the presence of phenolphthalein, such that the entire amount of suberic acid is neutralized. The titration requires 23.0mL of NaOH solution.

How many carbon atoms does the suberic acid molecule contain?

A. 2
B. 4
C. 6
D. 8

Problem proposed by Alex Jicu

Question 2 – An acid-base titration

A 0.500 mol sample of a weak monoprotic acid HA is dissolved in 1.00 L of water. It is titrated with 0.200 mol of NaOH. At this point in the titration, the pH of the solution is 4.75.

Later, more NaOH is added to reach the half-equivalence point, and the pH is measured to be 5.00.

What is the acid dissociation constant (Ka) of the acid HA?

A. 3.16×10^{-6}
B. 1.78×10^{-5}
C. 5.62×10^{-5}
D. 1.00×10^{-5}

Problem proposed by Thenura Wickramaratna

Question 3 – Super-heavy elements

As of now, the periodic table has 118 elements. However, the existence of elements with $Z>118$ was predicted until around $Z=172$. Which of the following options is correct about elements with high atomic numbers?

A. In the extended periodic table, electrons will start occupying the 8th electron shell which can be occupied by a maximum of 64 electrons
B. The element with $Z = 121$ has the electronic structure $[Og]8s^2 8p^1$
C. Oganesson doesn't have a full 6th shell
D. Oganesson has its 7th shell fully occupied

Problem proposed by Alex Jicu

Question 4 – Kinetics of an unusual reaction

The rate law of a reaction occurring in aqueous solution is given by the equation:

$$\text{rate} = k \times [H_3O^+]^x$$

It is observed that a decrease in the pH of the solution from 3 to 1, with no other changes, results in a 100 times increase in the reaction rate

A. 0
B. 1
C. 1.5
D. 2

Problem proposed by Fillios Memtsoudis

Question 5 – Hydrogen iodide decomposition

In a container, a quantity of $HI_{(g)}$ is introduced, and, at constant temperature, equilibrium is established in the following reaction:

$$2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$$

Which of the following expressions relates the equilibrium constant K_C to the yield α of the reaction?

A. $\alpha = \frac{1+2\sqrt{K_C}}{2}$

B. $\alpha = \sqrt{\frac{1+2K_C}{2}}$

C. $\alpha = \sqrt{\frac{2K_C}{1+2K_C}}$

D. $\alpha = \frac{2\sqrt{K_C}}{1+2\sqrt{K_C}}$

Problem proposed by Fillios Memtsoudis

Question 6 – Accident at Willy Wonka's factory

At Willy Wonka's factory, a 3.0 L tank consisting only of ammonia and a 6.0L tank consisting only of hydrochloric acid vapor was separated by a glass. However, the glass breaks and the two containers are now connected. The gases form dense white fumes instantly. Initially, each gas was at 1.0 atm and 25°C.

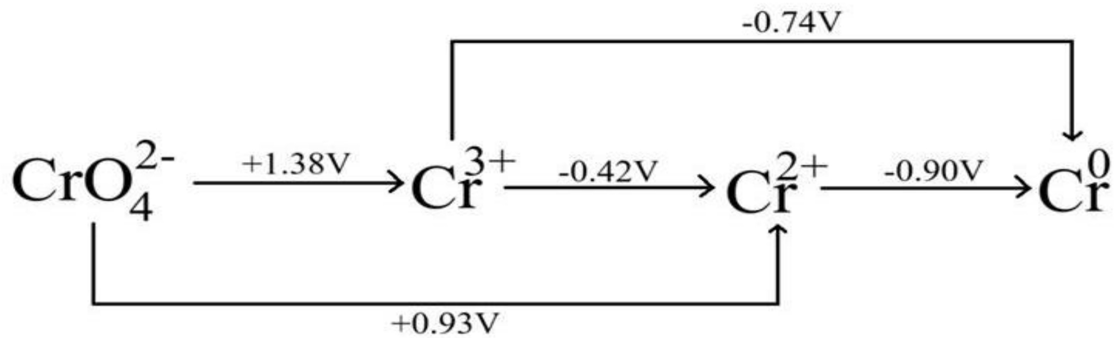
What is the final pressure in the room after the reaction?

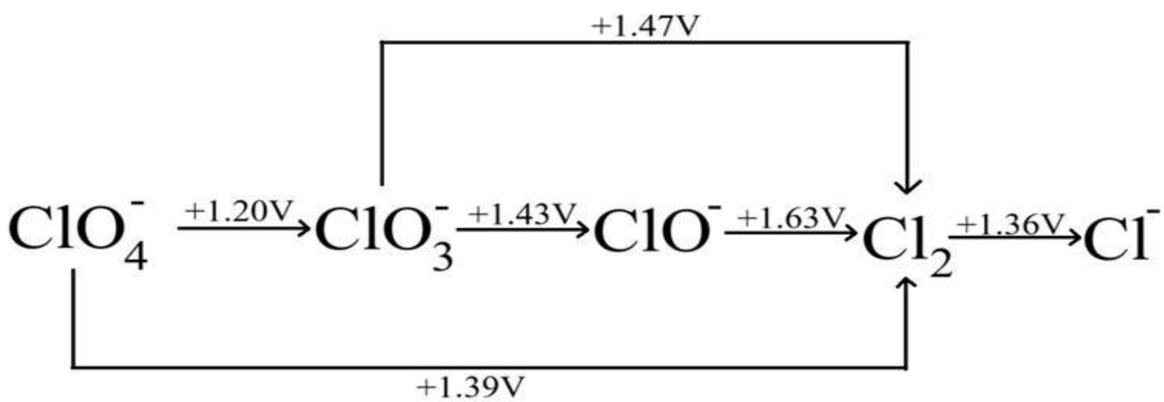
A. 0.33atm
B. 0.66atm
C. 0.83atm
D. 1.0atm

Problem proposed by Thenura Wickramaratna

Question 7 – Latimer Diagrams

Latimer diagrams are very useful visual ways of showing half-cell potentials for redox processes involving species of the same element. Below, the Latimer diagrams of chromium and chlorine (in standard conditions, at pH = 0) are given:





Using the provided Latimer diagrams, which of the following reactions is spontaneous under standard conditions?

(Hint: Identify the redox half reactions)

A. $3Cl_2 + 6NaOH \rightarrow NaClO_3 + 5NaCl + 3H_2O$
B. $2CrO_4^{2-} + 3Cl_2 + 4H^+ \rightarrow 2Cr^{3+} + 6ClO^- + 2H_2O$
C. $KClO_3 + 2Cl_2 + 2H_2O \rightarrow 4HClO + KClO$
D. $14Cr^{3+} + 6ClO_4^- + 32H_2O \rightarrow 14CrO_4^{2-} + 3Cl_2 + 64H^+$

Problem proposed by Alex Jicu

Question 8 – Boiling points of some usual compounds

Considering the intermolecular forces that occur in each of them, arrange the following chemical substances in order of increasing boiling points: CO_2, H_2O, $HCl, N_2, CaCO_3$:

A. $CO_2 < HCl < N_2 < CaCO_3 < H_2O$
B. $HCl < N_2 < H_2O < CO_2 < CaCO_3$
C. $N_2 < CO_2 < HCl < H_2O < CaCO_3$
D. $N_2 < CO_2 < H_2O < HCl < CaCO_3$

Problem proposed by Maria Mustatea

Question 9 – Some chemical reactions

Consider the following reactions involving some unknown compounds denoted by letters:

(1) $A + 2H_2O \rightarrow B + 2C + 2D$

(2) $B + 2E \rightarrow 3F + $ 2H2O

(3) $E + 2NaOH \rightarrow G + $ 2H2O

(4) $3F + 5NaOH \rightarrow 2G + H + 2H_2O$

It is known that C is an acid found in the stomach and D is a substance analogous to C. It is also given that F is a simple solid yellow substance and compounds B and E contain the element F.

Which of the following chemical reactions is not possible?

A. G + NaOH
B. H + NaOH
C. B + NaOH
D. D + G

Problem proposed by Alex Jicu

Question 10 – Acidity of hydrogen selenide and teluride

The following equilibria are both shifted to the left:

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

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

Based on this information, the order of the acids from strongest to weakest is:

A. HTe^{-}, HSe^{-}, H_2Te
B. HSe^{-}, H_2Te, HTe^{-}
C. H_2Te, HSe^{-}, HTe^{-}
D. H_2Te, HTe^{-}, HSe^{-}

Problem proposed by Fillios Memtsoudis

Question 11 – A puzzle about atoms

Consider 3 atoms, A, B and C and the following information about them.

-A and B have the same mass number.

-B and C are Isotopes

-A and C have the same number of neutrons

-A's mass number is larger than C's mass number by one unit

-B has the same number of neutrons as the most stable form of oxygen.

A has the same amount of neutrons as the most stable form of which element?

A. Chlorine
B. Hydrogen
C. Carbon
D. Nitrogen

Problem proposed by Jailson Godeiro

Question 12 – A Quantitative Analysis

A 100 mL solution contains a mixture of the two iron chlorides. An excess of 0.1 M $AgNO_3$ solution is added. After the reaction is complete, the solution is filtered, yielding 4.87 g of precipitate. A magnesium ribbon is then introduced into the aqueous filtrate. After a long period, the ribbon is removed and weighed, revealing a mass increase of 0.313 g.

Calculate the percentage concentrations of $FeCl_3$ and $FeCl_2$ in the initial solution, assuming it has a density of 1 g/cm^3.

A. 1.54% and 0.530%
B. 1.30% and 0.636%
C. 0.530% and 1.54%
D. 0.636% and 1.30%

Problem proposed by Bianca Buzas

Question 13 – Thermochemistry of neutralization

In a laboratory, a student wants to determine the molar enthalpy of neutralization between a strong acid (HCl) and a strong base (NaOH). The student adds 50.0 mL of 2.00 M HCl to 50.0 mL of 1.00 M NaOH in a calorimeter. The initial temperature of both solutions is 25.0°C, and the final temperature after mixing is 31.8°C. Assume the solutions have the same density and specific heat capacity as water (1.00 g/mL and 4.18 J/g°C, respectively), and that the calorimeter does not absorb heat.

What is the enthalpy of neutralization per mole of water formed?

A. -41.8 kJ/mol
B. -56.8 kJ/mol
C. -50.2 kJ/mol
D. -68.9 kJ/mol

Problem proposed by Thenura Wickramaratna

Question 14 – Electrochemical Cell

Two half-cells are set up as follows:

Half-cell A: A strip of zinc is placed in a solution of $ZnSO_4$.

Half-cell B: A strip of copper is placed in a solution of $CuSO_4$.

The two half-cells are connected by a salt bridge, and the metals are connected via a voltmeter.

Standard electrode potentials (E°):

$$Zn^{2+} + 2e^{-} \rightarrow Zn\ (E^{0} = -0.76V)$$

$$Cu^{2+} + 2e^{-} \rightarrow Cu\ (E^{0} = +0.34V)$$

Which of the following statements is correct about the above electrochemical cell?

A. Electrons will flow from the copper electrode to the zinc electrode
B. Zinc undergoes oxidation and acts as the cathode
C. Copper is reduced and the cell potential is 1.10V
D. The salt bridge allows the electrons to pass form one half-cell to another

Problem proposed by Filip Kilibarda

Question 15 – The Antiacid Tablet

A 1.00 g antacid tablet suspected to contain only $NaHCO_3$ and $CaCO_3$ is completely reacted with excess 1.00 M HCl. The resulting gas is fully absorbed in 100.0 mL of distilled water, forming carbonic acid (H_2CO_3):

After complete dissolution of CO_2, the pH of the solution is measured to be 4.16. Assume only carbonic acid contributes to the pH. Ka of H_2CO_3 = 4.3×10^{-7}

What is the mass percent of $CaCO_3$ in the original tablet?

A. 31.83%
B. 40.63%
C. 59.37%
D. 65.41%

Problem proposed by Thenura Wickramaratna

Question 16 – Unusual data about acetic acid

When discussing the strength of acids, we often talk about their acidity constant Ka. The acidity constant of an acid is the equilibrium constant for the reaction in which the acid protonates water. However, values like the Ka can be measured in a lot of other solvents.

Just like water, all solvents are characterized by a self-ionization constant (for the auto-protonation reaction $2HA \rightleftharpoons A^- + H_2A^+$). For acetic acid, that ionization constant is almost equal to that of water, $K = K_W = 10^{-14}$

The pKa of acetic acid (in water) is known to be 4.75.

The density of pure acetic acid is 1.05g/mL and the molar mass of acetic acid is 60g/mol (for the calculation of the molar concentration of acetic acid in pure form).

Find the pKb of acetic acid (when it's protonated as a base) in water:

A. 25.74
B. 23.25
C. 20.48
D. 17.50

(Hint: one of the approaches you can take is finding a cycle of reactions that lead to the sought reaction – similar to Hess' law)

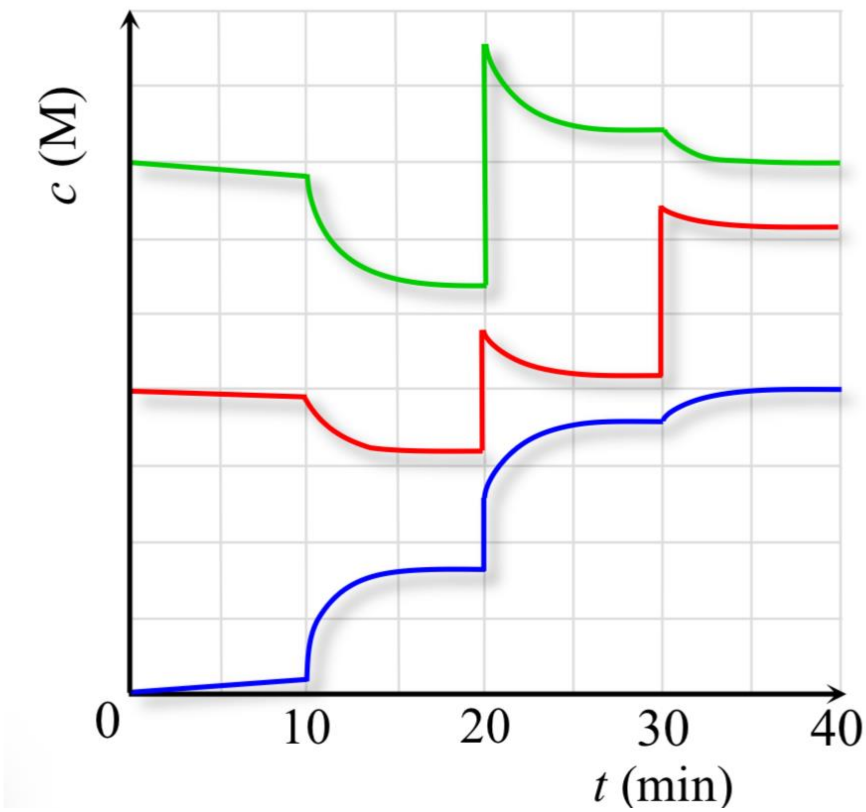
Problem proposed by Alex Jicu

Question 17 – Sulfur Dioxide Oxidation

Consider the following chemical equilibrium:

$$2SO_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2SO_{3\,(g)}$$

Quantities of $SO_{2\,(g)}$ and $O_{2\,(g)}$ are brought to react in a time period, during which various changes occur, including the addition of a catalyst. The graph below shows the concentrations of the three components in the gaseous phase, over the time interval 0-40 minutes.



At what moment was the catalyst added?

A. t = 0 min
B. t = 10 min
C. t = 20 min
D. t = 30 min

Problem proposed by Fillios Memtsoudis

Question 18 – Investigating Kinetics

The following experiment is done to determine the reaction rate constant of a generic reaction of the form (not balanced):

$$A + B \rightarrow \text{products}$$

The reaction was done three times, using different concentrations of A and B:

[A] (mol/L)	[B] (mol/L)	Rate (mol/L/min)
0.200	0.300	1.00×10^{-5}
0.400	0.300	1.60×10^{-4}
0.400	0.900	2.77×10^{-4}

What is the rate constant?

A. 1.28×10^{-2} $\text{mol}^{-7/2}\text{L}^{7/2}\text{min}^{-1}$
B. 1.28×10^{-2} $\text{mol}^{-9/2}\text{L}^{9/2}\text{min}^{-1}$
C. 1.14×10^{-2} $\text{mol}^{-7/2}\text{L}^{7/2}\text{min}^{-1}$
D. 1.14×10^{-2} $\text{mol}^{-9/2}\text{L}^{9/2}\text{min}^{-1}$

Problem proposed by Jailson Godeiro

Question 19 – Preparation of sulfuric acid

Oleum (or fuming sulfuric acid) is a mixture of SO_3 and H_2SO_4, which can act as a very strong acid frequently used in both inorganic and organic chemistry.

It is stable in anhydrous media, but in the presence of water, the sulfur trioxide reacts violently to produce sulfuric acid.

Consider 250g of oleum containing 20% SO_3 by mass. What mass of water is required to produce a 80% sulfuric acid aqueous solution?

A. 11.25g
B. 56.25g
C. 62.50g
D. 76.56g

Problem proposed by Alex Jicu

Question 20 – Finding composition of a mixture

A 4.00 g mixture of sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) is treated with excess hydrochloric acid:

- $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$
- $NaHCO_3 + HCl \rightarrow NaCl + CO_2 + H_2O$

The reaction produces 1.76 g of carbon dioxide gas. What is the mass percent of sodium carbonate (Na_2CO_3) in the original mixture?

A. 22.91%
B. 41.67%
C. 58.33%
D. 77.09%

Problem proposed by Thenura Wickramaratna

Question 21 – An Interesting Reaction

Consider the following reaction:

$$3C_6H_{12} + 2K_2Cr_2O_7 + 8H_2SO_4 \rightarrow 6A + 2B + 2C + 8H_2O$$

Knowing that C contains a metal with its 3d orbitals half-filled, the chemical substances A, B, C are:

A. $C_3H_6O, K_2SO_4, Cr_2(SO_4)_3$
B. $C_2H_5COOH, K_2SO_4, Cr_2(SO_4)_3$
C. $CO_2, KOH, Cr_2(SO_4)_3$
D. $C_3H_6O, K_2S, Cr_2(SO_4)_3$

Problem proposed by Butu “Jujen” Alexia

Question 22 – Halide Geometries

Consider the following molecules: $BeCl_2$, BF_3, PCl_5, and SF_6.

Each has a central atom bonded to surrounding atoms with different geometries.

Which of the following statements is correct, based only on the electron-pair geometry and number of bonded atoms?

A. $BeCl_2$ is linear because the central atom forms two bonds and has no lone pairs
B. BF_3 is tetrahedral because it forms three bonds and has one lone pair on boron
C. PCl_5 has a square pyramidal geometry due to repulsion from a lone pair on phosphorus
D. SF_6 has a distorted geometry because sulfur cannot bond with six fluorine atoms

Problem proposed by Filip Kilibarda

Question 23 – Thermodynamics of Hydrogen Production

Hydrogen gas (H_2) is a very promising element for energy storage in the effort to avoid the combustion of hydrocarbons and the increase of CO_2 emissions in the atmosphere. One method of producing H_2 through the decomposition of water and without the consumption of other raw materials is the sulfur–iodine thermochemical cycle, which is based on the following reactions:

1. $I_{2\,(g)} + SO_{2\,(g)} + 2H_2O_{(l)} \rightarrow 2HI_{(l)} + H_2SO_{4\,(l)}, \Delta H_1$
2. $H_2SO_{4\,(l)} \rightarrow SO_{2\,(g)} + H_2O_{(l)} + \frac{1}{2}O_{2\,(g)}, \Delta H_2$
3. $2HI_{(g)} \rightarrow I_{2\,(g)} + H_{2\,(g)}, \Delta H_3$

The sum $\Delta H_1 + \Delta H_2 + \Delta H_3$ is:

A. equal to zero
B. half of the inverse of the formation enthalpy of water
C. equal to the formation enthalpy of water
D. equal to the enthalpy change of $H_2O_{(l)} \rightarrow H_{2\,(g)} + \frac{1}{2}O_{2\,(g)}$

Problem proposed by Fillios Memtsoudis

Question 24 – Colors of two pH indicators

In the given table, the colors of two different pH indicators are given at different pH values. The indicators are bromocresol green (BG) and phenol red (PR).

The color code used is:

B = blue

G = green

O = orange

R = red

Y = yellow

Choose the correct option out of the following:

A. At pH = 6, BG is predominantly in its protonated from, while PR is still in its deprotonated form

B. The molar absorption coefficient for the basic form of the BG is the highest at $\lambda = 475\text{nm}$ (blue light)

C. The red form of PR is a Bronsted base

D. The three colors of BG indicate it's a diprotic acid, with the green form having only one proton

pH	Indicator	
	BG	PR
0	Y	Y
1	Y	Y
2	Y	Y
3	Y	Y
4	Y	Y
5	G	Y
6	B	Y
7	B	O
8	B	O
9	B	R
10	B	R
11	B	R
12	B	R
13	B	R
14	B	R

Problem proposed by Alex Jicu

Question 25 – A thermochemical cycle

Which of the following equations relates the standard enthalpy of formation of $CO_{(g)}$ with the standard enthalpy of combustion of carbon in the form of graphite (C_{graph}) and the standard enthalpy of combustion of $CO_{(g)}$?

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

B. $\Delta H_f(CO) = 2\Delta H_c(C_{graph}) - 2\Delta H_c(CO)$

C. $\Delta H_f(CO) = \Delta H_c(C_{graph}) + \Delta H_c(CO)$

D. $2\Delta H_f(CO) = \Delta H_c(C_{graph}) - 2\Delta H_c(CO)$

Problem proposed by Fillios Memtsoudis

Question 26 – Polar molecules

Boron forms very stable trihalides with the general formula BX_3. These compounds have trigonal planar structure. That means all the atoms are coplanar, the halogen atoms are found at the vertices of an equilateral triangle, while the boron atom is at the center of the triangle.

There exist some halides in which not all the halogen atoms are identical. One such compound is boron dibromide monochloride, BBr_2Cl. This mixed halide has almost the same geometry as that described before.

The dipole moment of the B-Cl bond is known to be 0.75D, while that of B-Br bond is known to be 0.55D, where 1D is called a Debye (a unit of dipole moment).

What is the net dipole moment of the boron dibromide monochloride molecule?

A. 0.00D
B. 0.20D
C. 0.35D
D. 1.30D

Problem proposed by Alex Jicu

Question 27 – Two equilibrium states

In a container, 1 mol of SO_2 and 1 mol of NO_2 are introduced and chemical equilibrium is reached:

$$SO_2 + NO_2 \rightleftharpoons SO_3 + NO$$

The amount of nitrogen dioxide at equilibrium is a mol. In another container, 2 mol of sulfur trioxide and 2 mol of nitrogen monoxide are introduced, and the same equilibrium is reached, at the same temperature. The amount of nitrogen dioxide at equilibrium in the second container is b mol.

What is the relationship between a and b?

A. a = b
B. a = 2b
C. 2a = b
D. We cannot know without the value of the equilibrium constant provided

Problem proposed by Fillios Memtsoudis

Question 28 – Finding the formula of a hydrate

Substance X is very commonly found as a pentahydrate, $X \cdot 5H_2O$. Upon heating, it turns into its monohydrate form, $X \cdot H_2O$.

It is known that, when heating 5.50g of pentahydrate, to form the monohydrate, 1.58g of water are formed. Using this, calculate the molecular mass of the unknown compound X:

A. 160
B. 178
C. 250
D. 313

Problem proposed by Alex Jicu

Question 29 – An unusual battery

Consider a battery whose electrodes are made of magnesium and silver. The reduction half-reactions and the standard potentials are:

$$Mg^{2+} + 2e^- \rightarrow Mg, E^0 = -2.37V$$

$$Ag^+ + e^- \rightarrow Ag, E^0 = +0.80V$$

Calculate the electric potential of the battery, and also calculate how long it takes for 10g of the anode to corrode if the electrical current is 10A.

A. 1.57V and 8×10^3s
B. 3.17V and 8×10^3s
C. 1.57V and 9×10^2s
D. 3.17V and 9×10^2s

Problem proposed by Jailson Godeiro

Question 30 – Thermochemical processes

Consider the formation of sodium chloride from sodium and chlorine. The enthalpy of formation of NaCl is equal to -411.20 kJ/mol. The following thermochemical data is provided:

- Sodium enthalpy of sublimation = 108.40 kJ/mol
- Sodium primary ionization energy (IE_1) = 495.80 kJ/mol
- Chlorine dissociation energy = 242.90 kJ/mol
- Chlorine electron affinity = -349.00 kJ/mol

One thermochemical process involved in the formation of NaCl was not specified in the list above. What is the process and what is its enthalpy?

A. NaCl lattice formation, with an enthalpy of -787.85 kJ/mol

B. Na to Cl electron transfer, with an enthalpy of -787.85 kJ/mol

C. NaCl lattice formation, with an enthalpy of -909.30 kJ/mol

D. Na to Cl electron transfer, with an enthalpy of -909.30 kJ/mol

Problem proposed by Alex Jicu