# Sample for
# Examination Problems
# Advanced Molecular Chemistry Course
# Tohoku University

## Chemistry

*If needed, use the following atomic weights*

*H, 1.00; C, 12.0; O, 16.0*

*In addition, in the problems, the unit L stands for liters.*

**Section I** Answer the following questions.

**Q1** A proton has approximately the same mass as

(a) a neutron
(b) an alpha particle
(c) a beta particle
(d) an electron

**Q2** Which element has the highest first ionization energy?

(a) sodium
(b) aluminum
(c) calcium
(d) phosphorus

**Q3** As the pressure of a gas is changed from 2 atm to 1 atm at a constant temperature, the volume of the gas

(a) decreases
(b) increases
(c) remains the same

**Q4** Which substance is produced by the Haber process?

(a) aluminum
(b) ammonia
(c) nitric acid
(d) sulfuric acid

**Q5** Which substance is an example of a network solid?

(a) nitrogen dioxide
(b) sulfur dioxide
(c) carbon dioxide
(d) silicon dioxide

**Section 1** has usually 10 to 18 multiple choice-questions.

**Section II** Answer the following questions.

**Q1** Ammonia will burn in the presence of a platinum catalyst to produce nitric oxide via the reaction:

$$4NH_3\,(g) + 5O_2\,(g) \rightarrow 4NO\,(g) + 6H_2O\,(g) \qquad \Delta H = ?$$

Using the following thermochemical reactions, determine the heat of reaction and indicate whether the reaction is exothermic or endothermic.

$N_2\,(g) + O_2\,(g) \rightarrow 2NO\,(g);\ \ \Delta H = 180$ kJ
$N_2\,(g) + 3H_2\,(g) \rightarrow 2NH_3\,(g);\ \ \Delta H = -\,91.6$ kJ
$2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(g);\ \ \Delta H = -483.7$ kJ

**Section III** Answer the following questions.

**Q1** The following data were collected at the endpoint of a titration performed to find the molarity of an HCl solution.

Volume of acid (HCl) used = 14.4 mL
Volume of base (NaOH) used = 22.4 mL
Molarity of standard base (NaOH) = 0.20 M

What is the molarity of the acid solution?

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# Physics

**Section 1**

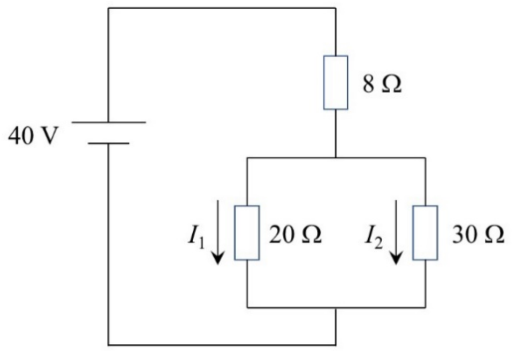
Answer the following questions by selecting proper choices

**Q1** Two objects move toward each other, collide, and separate. If there was no net external force acting on the objects, but some kinetic energy was lost, then

(a) the collision was elastic and total linear momentum was conserved.
(b) the collision was elastic and total linear momentum was not conserved.
(c) the collision was not elastic and total linear momentum was conserved.
(d) the collision was not elastic and total linear momentum was not conserved.

**Q2** A circuit contains three resistors and one battery, as shown below. The currents flow through the resister of 20 Ω and 30 Ω are $I_1$ and $I_2$. Calculate the ratio of $I_1$ to $I_2$, $\frac{I_1}{I_2}$.

(a) 1
(b) $\frac{2}{3}$
(c) $\frac{3}{2}$
(d) 2




**Q3** What is the wavelength of a 4 Hz wave that travels with a speed of 20 m/s?

(a) 0.25 m
(b) 0.5 m
(c) 1 m
(d) 5 m

**Q4** A current of 2.0 A flows through a resistor with an electrical resistance of 100 Ω. Select the correct power consumed by the resistor.

(a) 50 W
(b) 100 W
(c) 200 W
(d) 400 W

**Q5** The pressure of ideal gas in a container of 3 $m^3$ volume is $2.0 \times 10^4$ $N/m^2$ at 500 K. Which is the suitable number of molecules in the container? The gas constant is 8.31 J/(mol K) and Avogadro's constant is $6.02 \times 10^{23}$.

(a) $8.7 \times 10^{24}$
(b) $1.2 \times 10^{24}$
(c) $8.7 \times 10^{23}$
(d) $1.2 \times 10^{23}$

**Section II**

Answer the following problems.

Consider a rail with loop as shown in Figure 1. The loop BCDEF is an orbit with a radius $r$ in a vertical plane. Consider the motion of the ball P with a mass $m$, which starts from the point A at the initial velocity of 0. The height of point A from the horizontal plane GB is $h$. The acceleration of gravity is $g$. Friction, air resistance and rail thickness can be neglected.

Answer the following questions using the necessary symbols among $m, g, h, r, \theta$.

**Q1.1** Ball P moves through points B, C, D, E, F along the rail and reaches point B again. Express the speed $v_B$ of ball P using $g$ and $h$ when passing point B for the first time.

**Q1.2** Express the speed $v_E$ of ball P when passing point E with the maximum height in the loop.

**Q1.3** Express the magnitude of the normal force $N_E$ from the rail at point E.

**Q1.4** Express the minimum value of $h$, $h_1$, at which ball P goes around the loop without leaving the rail.

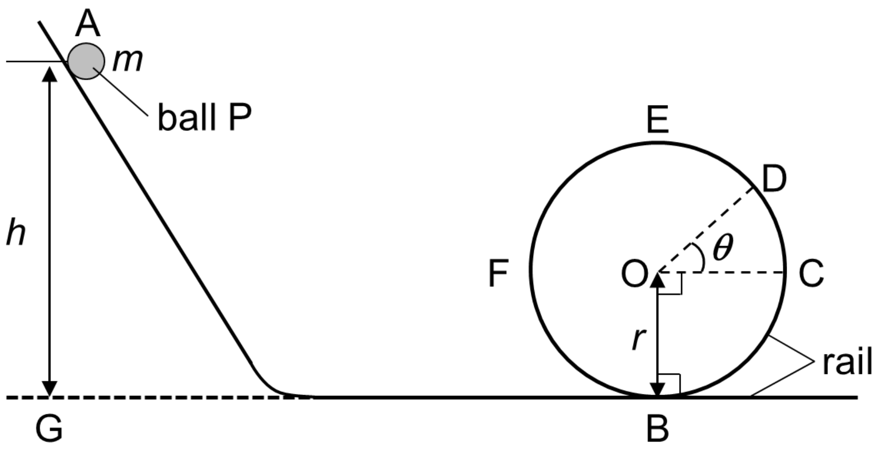



Figure 1

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# Mathematics

**Section 1**

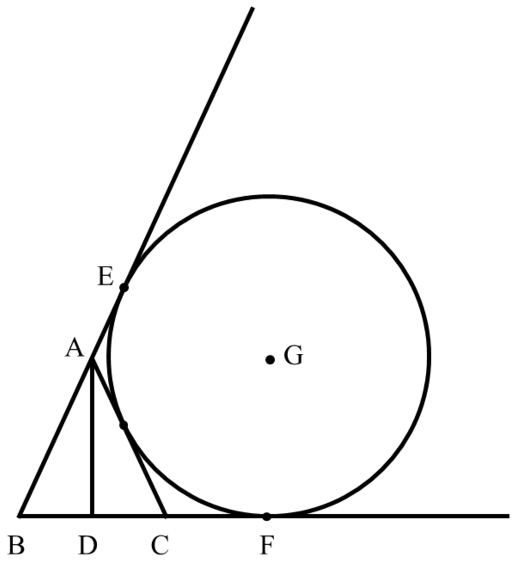
**Q1** Consider the two equations;

$$A = x^3 + px^2 + 2x + 3,$$
$$B = x^3 - 3x + 2,$$

where $p$ is a real number. If the quotient obtained by the division of A by B is $x$=1, find the value of P.

**Q2** As shown in the figure, triangle ABC is isosceles with AB = AC. AD is perpendicular to BC. G is the center of the circle. Prove AD = GF. Fill in the boxes $\boxed{\text{u}}$ ~ $\boxed{\text{z}}$ with A ~ G.

2∠EAG = ∠E $\boxed{\text{u}}$ $\boxed{\text{v}}$ = ∠ABC + ∠B $\boxed{\text{w}}$ $\boxed{\text{x}}$ = 2∠ABC
Accordingly, ∠EAG = ∠ABC. Thus, lines $\boxed{\text{y}}$ $\boxed{\text{z}}$ and BF are parallel. In addition, ∠ADC = ∠GFD = 90°. Thus, ADFG is a rectangle and AD = GF.




**Q3** Given the following function of x,

$$f(x) = \log_2(x + a) - \log_2 x$$

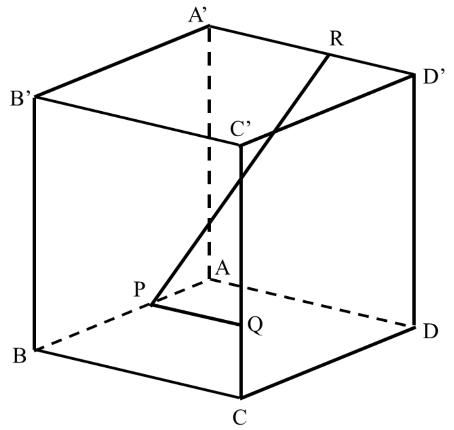
where a > 0, find the value of a that satisfies $f(2) = 1$.

**Section II**

Consider a regular hexahedron ABCD-A'B'C'D' shown in the figure. The points P, Q, and R divide sides AB, CC', and D'A', respectively, in the following ratio ($0 < s < 1$).

AP : PB = $s : 1 - s$
CQ : QC' = $s : 1 - s$
D'R : RA' = $s : 1 - s$

**Q1** Let the vectors $\overrightarrow{\mathrm{AB}} = \vec{x}$, $\overrightarrow{\mathrm{AD}} = \vec{y}$, and $\overrightarrow{\mathrm{AA'}} = \vec{z}$. Express the vectors $\overrightarrow{\mathrm{PQ}}$ and $\overrightarrow{\mathrm{PR}}$ in terms of $\vec{x}$, $\vec{y}$ and $\vec{z}$.




**Q2** Find the inner product of the vectors $\overrightarrow{\mathrm{PQ}}$ and $\overrightarrow{\mathrm{PR}}$.

**Q3** Find the angle $\angle$RPQ.