Fizika

1
kurs

MAVZU: Molekulyar-kinetik nazariyasiga, izojarayonlar va termodinamika qonunlariga doir masalalar yechish

O‘qituvchi:

“TIQXMMI” MTU FIZIKA va KIMYO KAFEDRASI

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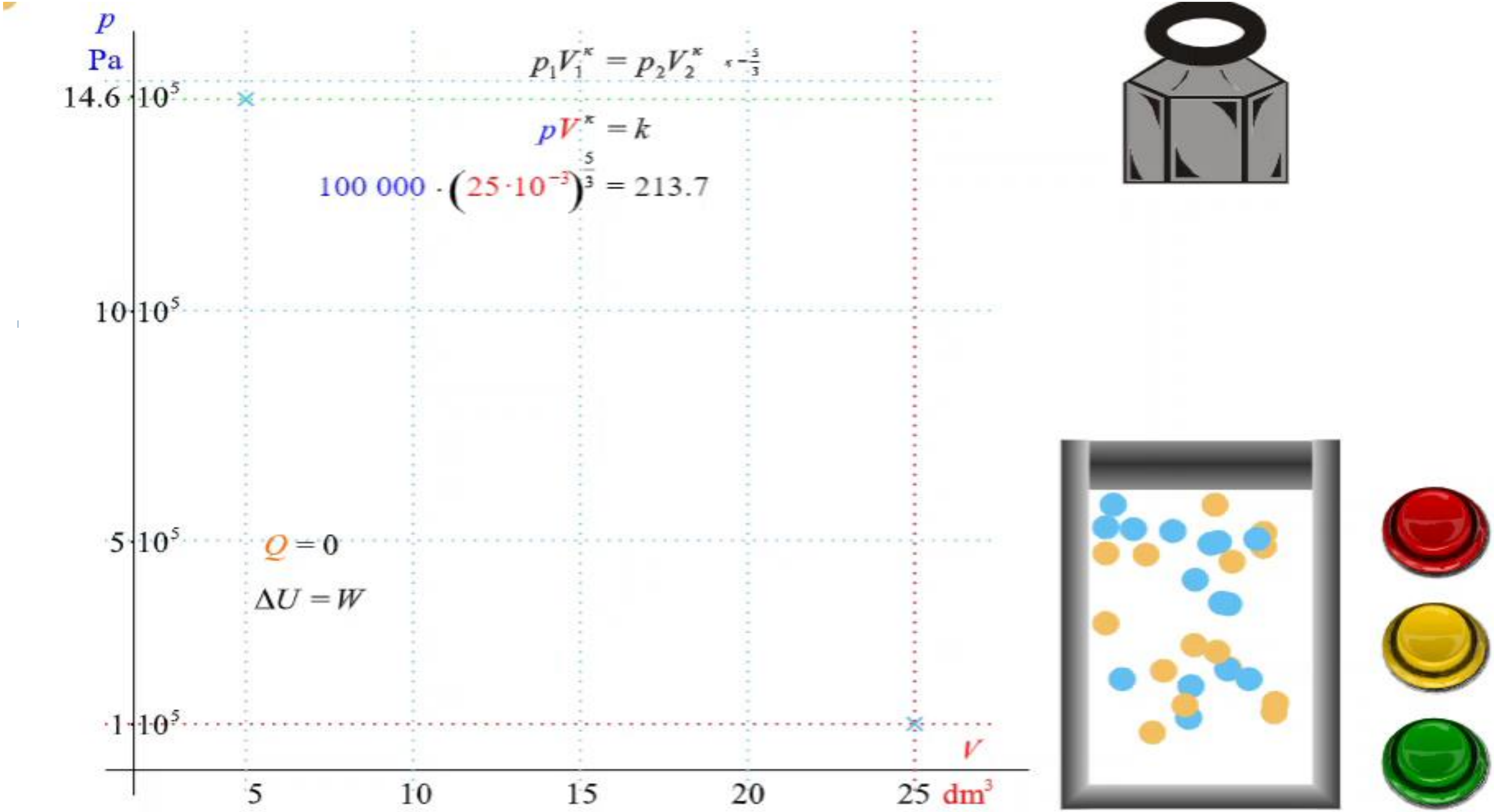
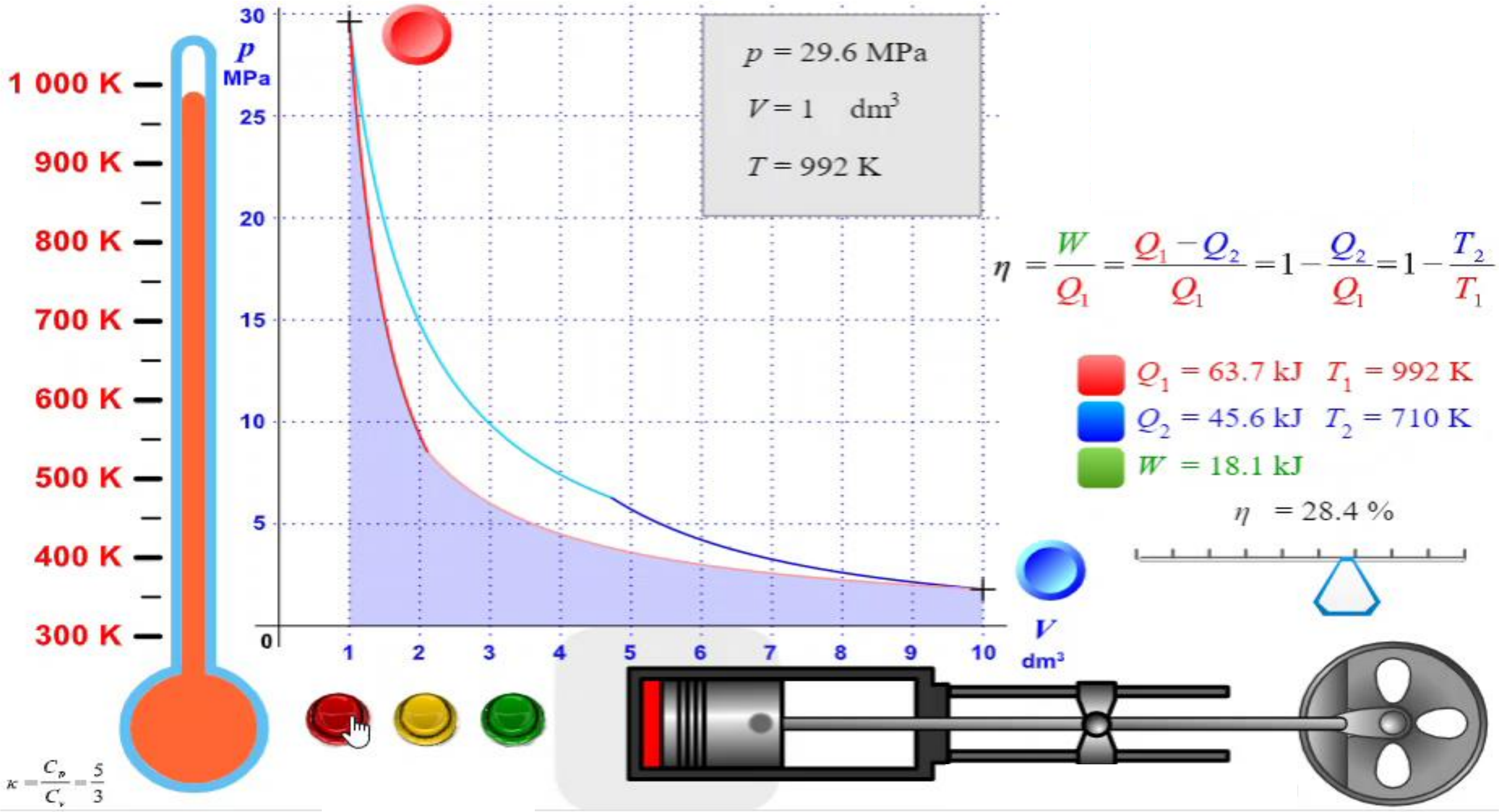
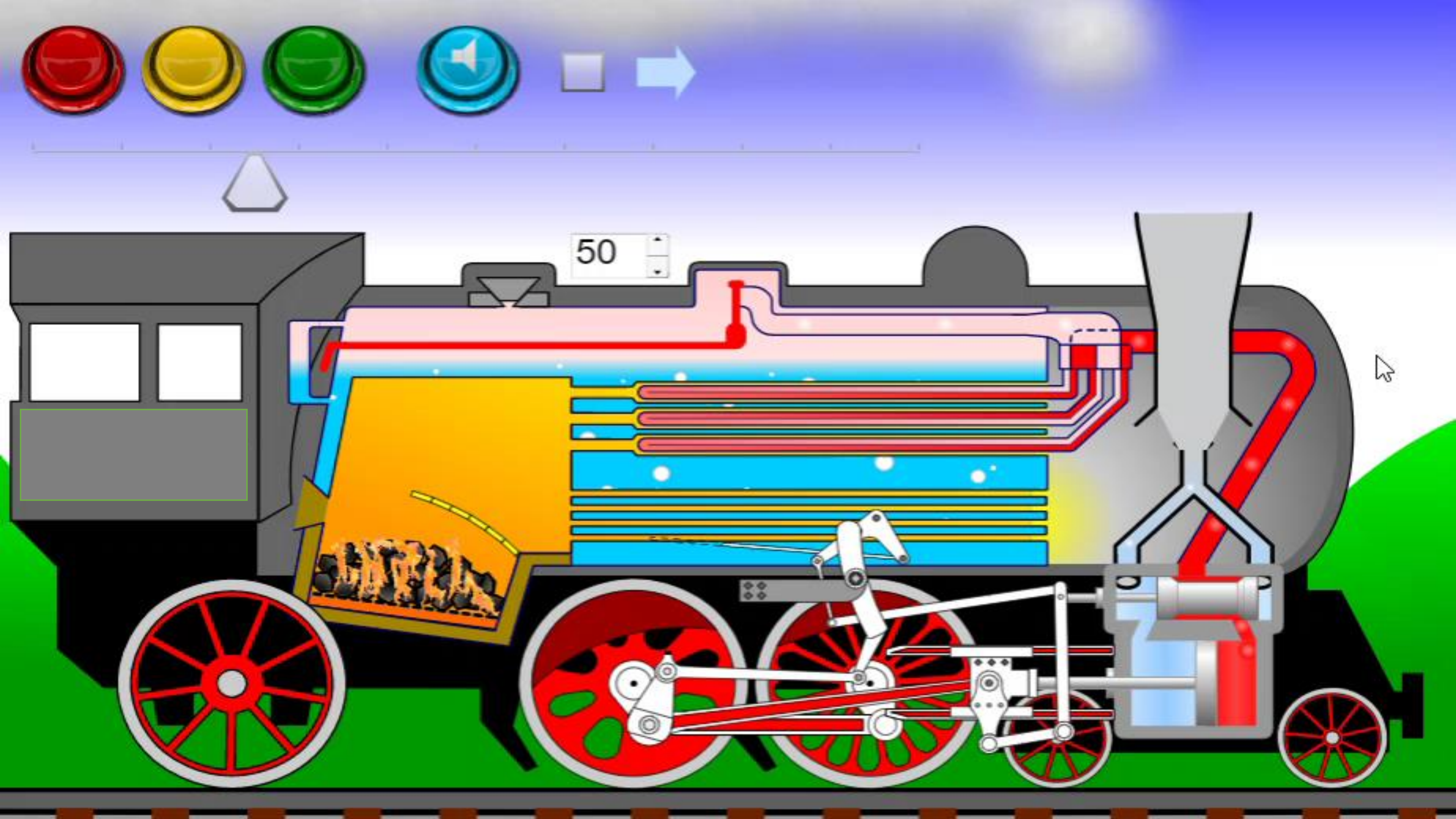


p
Pa
$14.6 \cdot 10^5$
$10 \cdot 10^5$
$5 \cdot 10^5$
$1 \cdot 10^5$
$p_1 V_1^{\kappa} = p_2 V_2^{\kappa} \quad \kappa = \frac{5}{3}$
$p V^{\kappa} = k$
$100\,000 \cdot \left(25 \cdot 10^{-3}\right)^{\frac{5}{3}} = 213.7$
$Q = 0$
$\Delta U = W$
V
5
10
15
20
25
dm^3



1 000 K
900 K
800 K
700 K
600 K
500 K
400 K
300 K
p MPa
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10
V dm³
$p = 29.6$ MPa
$V = 1$ dm^3
$T = 992$ K
$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$
$Q_1 = 63.7$ kJ $T_1 = 992$ K
$Q_2 = 45.6$ kJ $T_2 = 710$ K
$W = 18.1$ kJ
$\eta = 28.4$ %
$\kappa = \frac{C_p}{C_v} = \frac{5}{3}$


50

Ideal gazlar Mendeleyev - Klapeyron holat tenglamasiga bo'ysunadi:

$$pV = \frac{M}{\mu} RT$$

bunda p-gazning bosimi, V-uning hajmi, T-absolyut harorat, M - gazning massasi, μ- bir kilomol gazning massasi, R - gaz doimiysi, $\frac{M}{\mu}$ nisbatan kilomollar sonini beradi.

SI birliklar sistemasida gaz doimiysining son qiymati R-8,31·10^3 j/kmol·grad ga teng.

Dalton qonuniga ko'ra, gaz aralashmasining bosimi ularning parsial bosimlari yig'indisiga, ya'ni har bir gaz alohida olinganida mavjud haroratda bir o'zi butun hajmni to'ldirgandagi bosimlar yig'indisiga teng bo'ladi.

Gazlar kinetik nazaryasining asosiy tenglamasi quyidagi ko'rinishga egadir:

$$p = \frac{2}{3} n \overline{W_0} = \frac{2}{3} n \frac{m\overline{\upsilon^2}}{2},$$

bunda n - hajm birligida molekulalarning soni, $\overline{W_0}$ -bitta molekula ilgarilanma harakatining o'rtacha kinetik energiyasi, m-molekulaning massasi va $\sqrt{\overline{\upsilon^2}}$ – molekulaning o'rtacha kvadratik tezligi.

Bu kattaliklarni quyidagi formulalardan aniqlash mumkin.

Hajm birligidagi molekulaning soni

$$n = \frac{p}{kT}$$

bunda $k = \frac{R}{N_0}$ - Bolsman doimiysi, N_0 - Avogadro soni. $R=8,31\cdot10^3$ j/kmol·grad va $N_0=6,02\cdot10^{26}$ $kmol^{-1}$ bo'lganligi uchun, $k=1,38\cdot10^{-23}$ j/grad=1,38·10 erg/grad bo'ladi.

Molekula ilgarilanma harakatining o'rtacha kinetik energiyasi:

$$\overline{W_0} = \frac{3}{2}kT$$

Molekulaning o'rtacha kvadratik tezligi:

$$\sqrt{\overline{\upsilon^2}} = \sqrt{\frac{3RT}{\mu}} = \sqrt{\frac{3RT}{m}}$$

shu bilan birga

$$m = \frac{\mu}{N_0}$$

Molekulalarning issiqlik harakat energiyasi (gazning ichki energiyasi)

$$W = \frac{M}{\mu} \cdot \frac{i}{2} RT$$

bunda i - molekulaning erkinlik darajasi.

C molekulyar va c solishtirma issiqlik sig‘imlari quyidagicha o'zaro bog’langandir:

$$C = \mu c$$

O'zgarmas hajmdagi gazning molekulyar issiqlik sig’imi

$$C_v = \frac{i}{2} R$$

o’zgarmas bosimdagi $C_p + C_v = R$

Bundan ko'rinadiki, molekulyar issiqlik sig’imi gaz molekulalari erkinlik darajasining soni bilan to'liq aniqlanadi. Bir atomli gazlar uchun $i = 3$ bo'lib;

$C_v = 12{,}5 \cdot 10^3$ j/kmol· grad $\cong$ 3 kal/mol·grad,

$C_p = 20{,}8 \cdot 10^3$ j/kmol·grad $\cong$ 5 kal/mol·grad

Ikki atomli gazlar uchun $i = 5$ bo'lib,

$C_v = 20{,}8 \cdot 10^3$ j/kmol·grad $\cong$ 5 kal/mol·grad

$C_p = 29{,}1 \cdot 10^3$ j/kmol·grad $\cong$ 7 kal/mol·grad

Ko'p atomli gazlar uchun $i = 6$ bo'lib,

$C_v = 24{,}9 \cdot 10^3$ j/kmol ·grad $\cong$ 6 kal/mol· grad,

$C_p = 33{,}2 \cdot 10^3$ j/kmol ·grad $\cong$ 8 kal/mol· grad, Molekulalarning tezliklar bo'yicha taqsimot qonuni (Maksvell qonuni), nisbiy tezliklari u dan $u + \Delta u$ gacha bo’lgan intervalda yotgan molekulalar soni ΔN ni topishga imkon beradi:

$$\Delta N = \frac{4}{\sqrt{\pi}} \cdot N \cdot e^{-u^2} \cdot u^2 \cdot \Delta u$$

bu yerda $u = \frac{\vartheta}{\vartheta_e}$ nisbiy tezlik bo'lib, υ - berilgan tezlik va $\vartheta_e = \sqrt{\frac{2RT}{\mu}}$ - ehtimolligi eng katta tezlik. Δu tezlik u ga nisbatan kichik bo’lgan, nisbat tezliklarning interval kattaligi.

Molekulalarning tezliklar bo'yicha taqsimot qonuniga masalalar yechishda har xil u uchun $\frac{\Delta N}{N \cdot \Delta u}$ ning qiymati berilgan 10-jadvaldan foydalanish qulaydir.

u	ΔN/N·Δu		ΔN/ N·Δu	u	ΔN/ N·Δu
0	0	0,9	0,81	1,8	0,29
0,1	0,02	1,0	0,83	1,9	0,22
0,2	0,09	1,1	0,62	2,0	0,16
0,3	0,18	1,2	0,78	2,1	0,12
0,4	0,31	1,3	0,71	2,2	0,09
0,5	0,44	1,4	0,63	2,3	0,06
0,6	0,57	1,5	0,54	2,4	0,04
0,7	0,68	1,6	0,46	2,5	0,03
0,8	0,76	1,7	0,36		

Molekulaning o'rtacha arifmetik tezligi $\bar{\upsilon} = \sqrt{\frac{8RT}{\pi\mu}}$

Ko'pchilik hollarda tezligi berilgan u tezlikning qiymatidan ortiq bo'lgan molekulalarning N_x sonini bilish muhimdir. 11- jadvalda $\frac{N_x}{N} = F(u)$ ning qiymati berilgan, bunda N - molekulalarning umumiy soni.

u	N_k/N	u	N_k/N
0	1,000	0,8	0,734
0,2	0,994	1,0	0,572
0,4	0,957	1,25	0,374
0,5	0,918	1,5	0,213
0,6	0,868	2,0	0,046
0,7	0,808	2,5	0,0057

Barometrik formula gaz bosiminnng og'irlik kuchi maydonida balandlikka qarab kamayishini ifodalaydi;

$$P_h = P_0 \ell^{-\frac{\mu g h}{RT}}$$

bunda p_h- gazning h balandlikdagi bosimi, p_0- gazning h=0 balandlikdagi bosimi, g-og'irlik kuchining tezlanishi. Bu formula taqribiydir, chunki balandliklarning farqi katta bo'lganda T temperaturani bir xil deb bo'lmaydi.

Gaz molekulasi erkin yugurish yo'lining o'rtacha uzunligi

$$\bar{\lambda} = \frac{\bar{\lambda}}{z} = \frac{1}{\sqrt{2}\pi\sigma^2 \cdot n}$$

Bunda υ- o'rtacha arifmetik tezlik, z-har bir molekulaning qolgan molekulalar bilan vaqt birligi ichida o'rtacha to'qnashishlar soni, δ-molekulaning effektiv diametri va n - hajm birligidagi molekulalar soni.

Barcha molekulalarni vaqt birligi ichida bir birlik hajmda umumiy to'qnashishlar soni quyidagiga teng:

$$Z = \frac{1}{2}\bar{z}\,n$$

Diffuziya natijasida Δt vaqt ichida ko'chirilgan massa M quuyidagi tenglamadan aniqlanadi:

$$M = -D\frac{\Delta p}{\Delta x}\cdot\Delta S\cdot\Delta t$$

bunda $\frac{\Delta p}{\Delta x}$-yuz ΔS ga tik yo'nalishdagi zichlik gradienti va D-diffuziya koeffitsienti bo’lib, quyidagiga teng;

$$D = \frac{1}{3}\bar{\upsilon}\,\bar{\lambda}$$

Bu yerda $\bar{\upsilon}$-o’rtacha tezlik, $\bar{\lambda}$ -molekula erkin yugurish yo’lining o'rtacha uzunligi.

Gazning Δt vaqt ichida ko’chirilgan harakat miqdori gazdagi ichki ishqalanishning kuchi F ni aniqlaydi:

$$F = -\eta\frac{\Delta v}{\Delta x}\cdot\Delta S$$

bunda $\frac{\Delta v}{\Delta x}$-yuz ΔS ga tik yo'nalishdagi gaz oqimining tezlik gradiyenti, η-ichki ishqalanish koeffitsienti (dinamik yopishqoqlik)

$$\eta = \frac{1}{3}\bar{\upsilon}\,\bar{\lambda}\,\text{p}$$

Issiqik o'tkazuvchanlik natijasida Δt vaqt ichida ko'chirilgan issiqlik miqdori quyidagiga teng

$$Q = -K\frac{\Delta T}{\Delta x}\cdot\Delta S\cdot\Delta t$$

bunda $\frac{\Delta T}{\Delta x}$-yuz ΔS ga tik yo'nalishdagi temperatura gradiyenti, K -issiqlik o'tkazuvchanlik koeffitsienti, y:

$$K = \frac{1}{3}\bar{\upsilon}\,\bar{\lambda}c_v p$$

ga teng.

Termodinamikaning birinchi qonuni quyidagi ko'rinishda yozilishi mumkin

$$dQ = dW + dA$$

bunda dQ-gazning olgan issiqlik miqdori, dW-gaz ichki energiyasining o'zgarishi va dA=pdV gazning hajmi o'zgarganda uning bajargan ishi. Gazning ichki energiyasining o'zgarishi

$$dW = \frac{M}{\mu}\cdot\frac{i}{2}RdT$$

bunda dT- haroratning o’zgarishi. Gazning hajmi o'zgarganda bajarilgan to'la ish

$$A = \int_{V_1}^{V_2} p dV .$$

Gazning hajmi izotermik o'zgarganda bajarilgan ish,

$$A=RT\frac{M}{\mu}\ln\frac{V_2}{V_1}$$

Adiabatik protsessda gaz bosimi bilan hajmining o'zaro bog’lanishi Puasson tenglamasi bilan ifodalanadi

$$pV=const,$$

ya’ni

$$\frac{p_1}{p_2} = \left(\frac{V_2}{V_1}\right)^x$$

bunda

$$x = \frac{S_p}{S_v}$$

Puasson tenglamasini quyidagi ko'rinishda ham yozish mumkin

$$TV^{x-1} = const$$

ya'ni

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{x-1}$$

yoki

$$T \cdot p^{\frac{x-1}{x}} = const,$$

ya'ni

$$\frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{x-1}{x}} = \left(\frac{p_2}{p_1}\right)^{\frac{1-x}{x}}$$

Gazning hajmi adiabatik o'zgarganda bajarilgan ish, quyidagi formuladan topiladi:

$$A = \frac{RT}{x-1} \cdot \frac{M}{\mu}\left[1 - \left(\frac{V_1}{V_2}\right)^{x-1}\right] = \frac{RT_1}{x-1} \cdot \frac{M}{\mu}\left(1 - \frac{T_2}{T_1}\right) = \frac{P_1 V_1 (T_1 - T_2)}{(x-1)T_1},$$

bunda p_1 va V_1- gazning T_1 haroratdagi bosimi va hajmi.

Politropik protsessning tenglamasi quyidagi ko'rinishda ifodalanadi

$$pV^n = const$$

yoki

$$P_1 V_1^n = P_2 V^n{}_2$$

bunda n - politrop ko'rsatkichi (1 < n < x).

Issiqlik mashinasining foydali ish koeffitsienti

$$\eta = \frac{Q_1 - Q_2}{Q_1}$$

bunda Q_1- ishchi jismga berilgan issiqlik miqdori va Q_2- sovitgichga berilgan issiqlik miqdori. Karnoning ideal sikli uchun f. i. k.

$$\eta = \frac{T_1 - T_2}{T_1}$$

bundaT_1- isitgichning harorati,T_2-sovitgichning harorati.
B va A ikkita holatdagi $S_B - S_A$ farqi quyidagi formuladan aniqlanadi.

$$S_B - S_A = \int_A^B \frac{dQ}{T}$$

5.1. 2 *g* azot 2 *atm* bosim ostida 820 sm^3 hajmni egallasa, uning harorati qanday bo'ladi?

5.2. 20^0C haroratda 750 *mm* sim. ust. bosimda 10 *g* kislorod qanday hajmni egallaydi?

5.3. Sig'imi 12 *l* bo'lgan ballonda $8{,}1\cdot10^6$ N/m^2 bosim va 17^0C haroratda azot to'ldirilgan. Ballonda qancha azot bor?

5.4. Og'zi mahkam berkitilgan shishadagi havoning 7^0C haroratda bosimi 1*atm*. Shisha isitilganda havo bosimi 1,3 *atm* ga yetganda tiqin otilgan. Shisha qanday haroratgacha isitilganligi topilsin.

5.5. 6,4 *kG* kislorod sig'adigan ballon devori 20^0C haroratda 160 *kG/sm*^{2} bosimga chidasa, uning eng kichik hajmi qanday bo'ladi?

5.6. Ballonda $10^7 N/m^2$ bosimli 10 kg gaz bo'lgan. Ballondagi bosim $2{,}5.10^6$ n/m^2 ga teng bo'lishi uchun ballondan qancha miqdor azotni olish kerak? Azotni harorati o'zgarmas deb hisoblansin.

5.7. 27 ^{0} C haroratda 760 mm sim. ust. bosimli 25 l oltingugurt gazi (SO_2) ning massasi topilsin.

5.8. Balandagi 5m va polining yuzi 200 m^2 bo'lgan auditoriyadagi havoning massasi topilsin. Binoning harorati 17°C, bosimi 750 mm. Sim.ust.ga teng. (Bir kilomol havoning massasi 2,9 kg/mol deb olinsin.)

5.9. Binoni to'ldirib turgan qishdagi (7 ^{0}C) havoning og'irligi yozdagi (37°C) havoning og'irligidan necha marta katta? Bosim bir xil deb olinsin.

5.10. 1) 0°C va 2) 100 ^{0}C haroratlar uchun 0,5 g vodorodning izotermalari chizilsin.