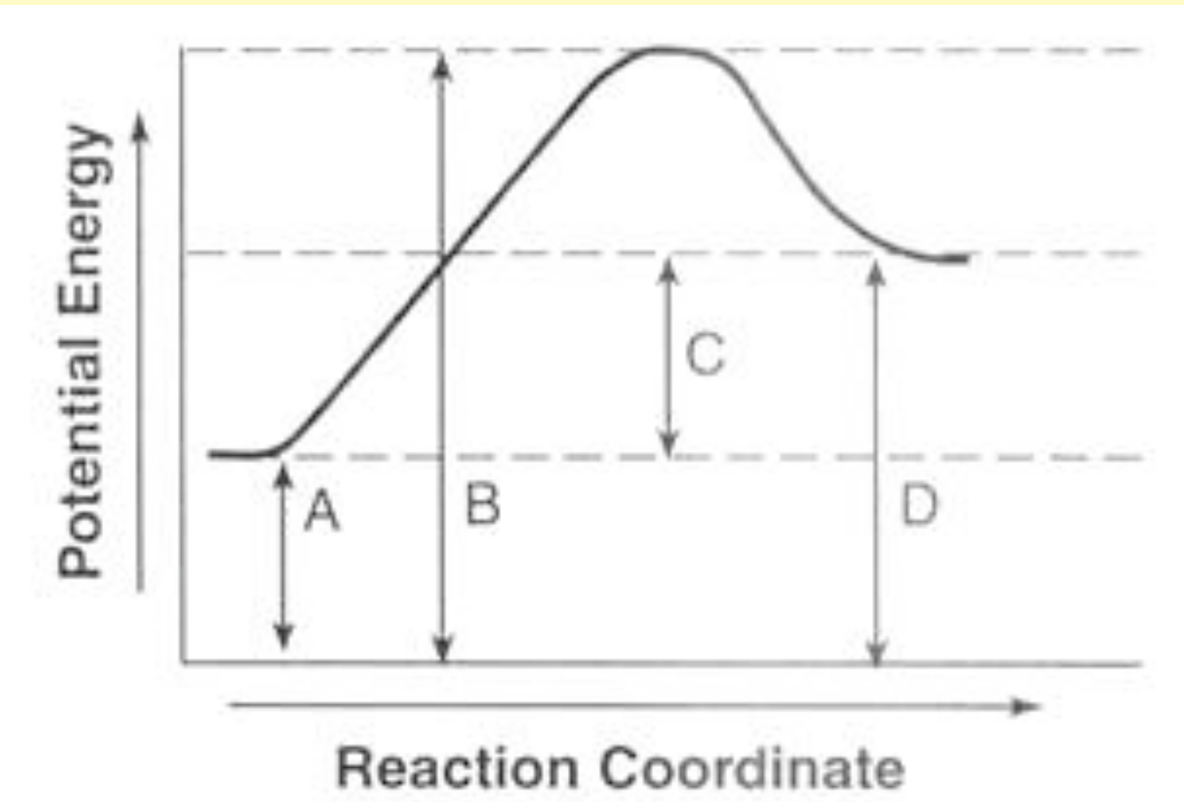
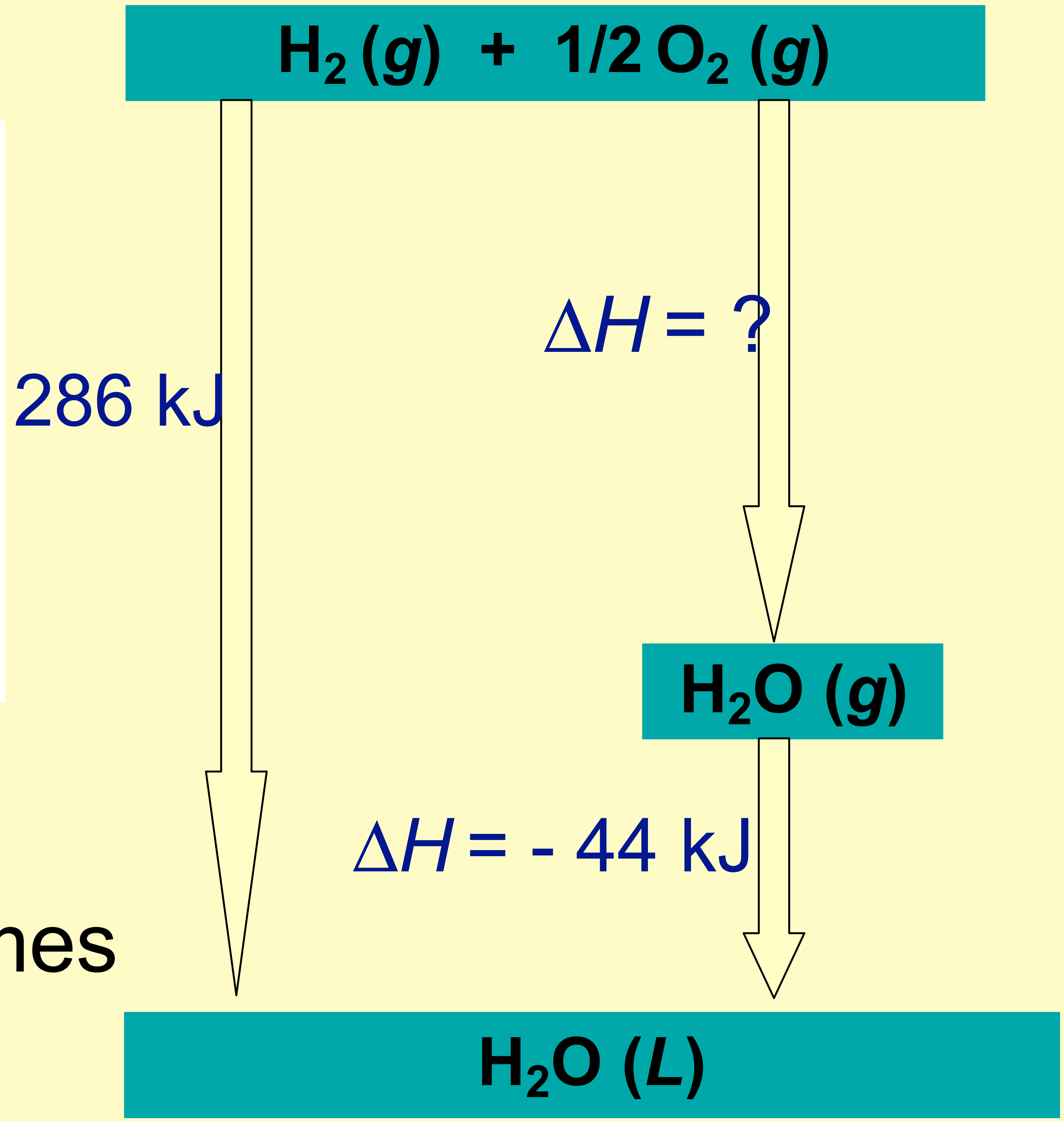
Thermochemistry

Chapter 5

No Calculators

Both of these sketches are called an *Energy Diagrams*

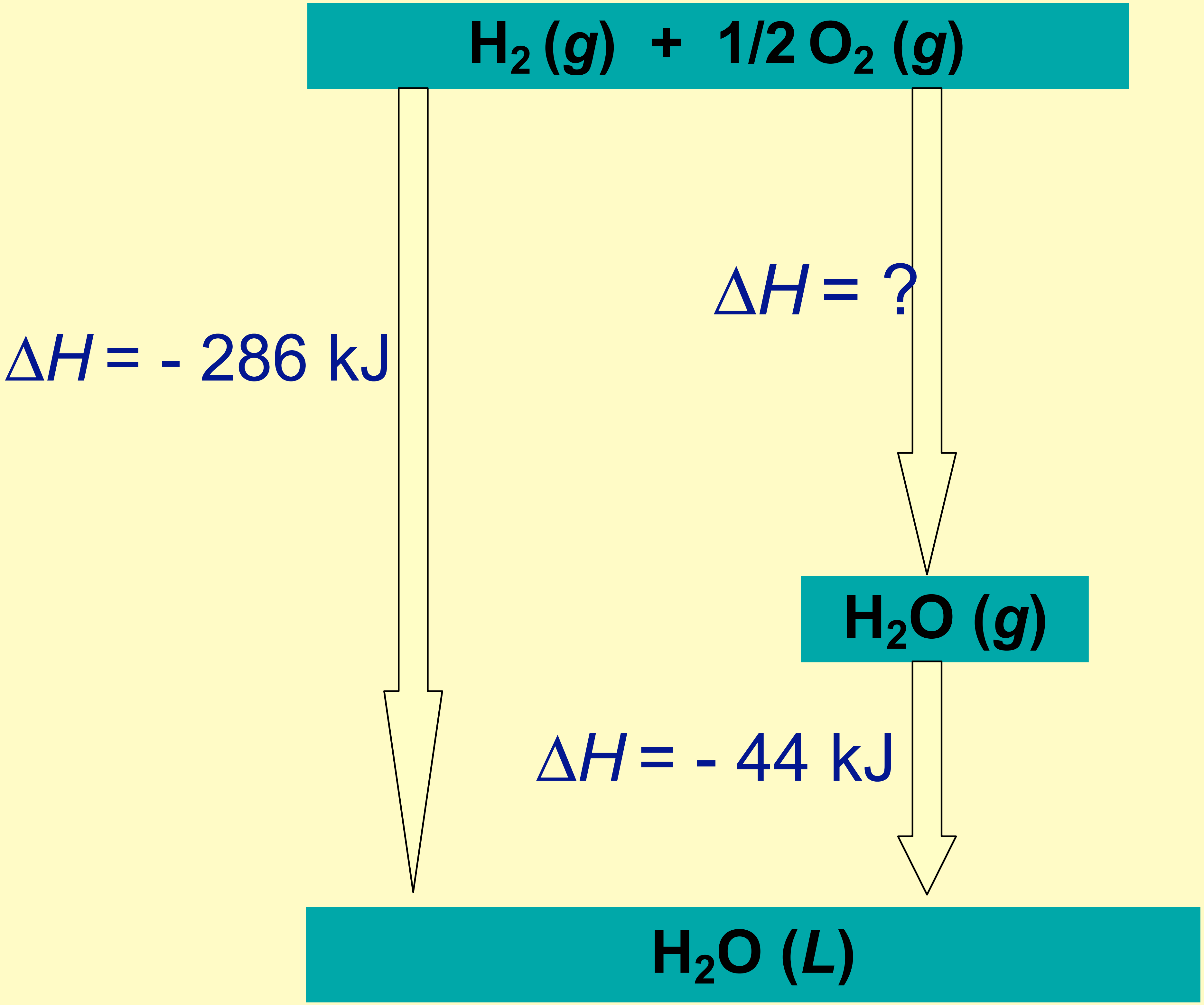




The AP Exam sometimes refers to them as a *Potential Energy Diagrams*

What is the value of the unknown ΔH in the energy diagram below?

1. +330 kJ
2. -330 kJ
3. +286 kJ
4. -242 kJ
5. +242 kJ



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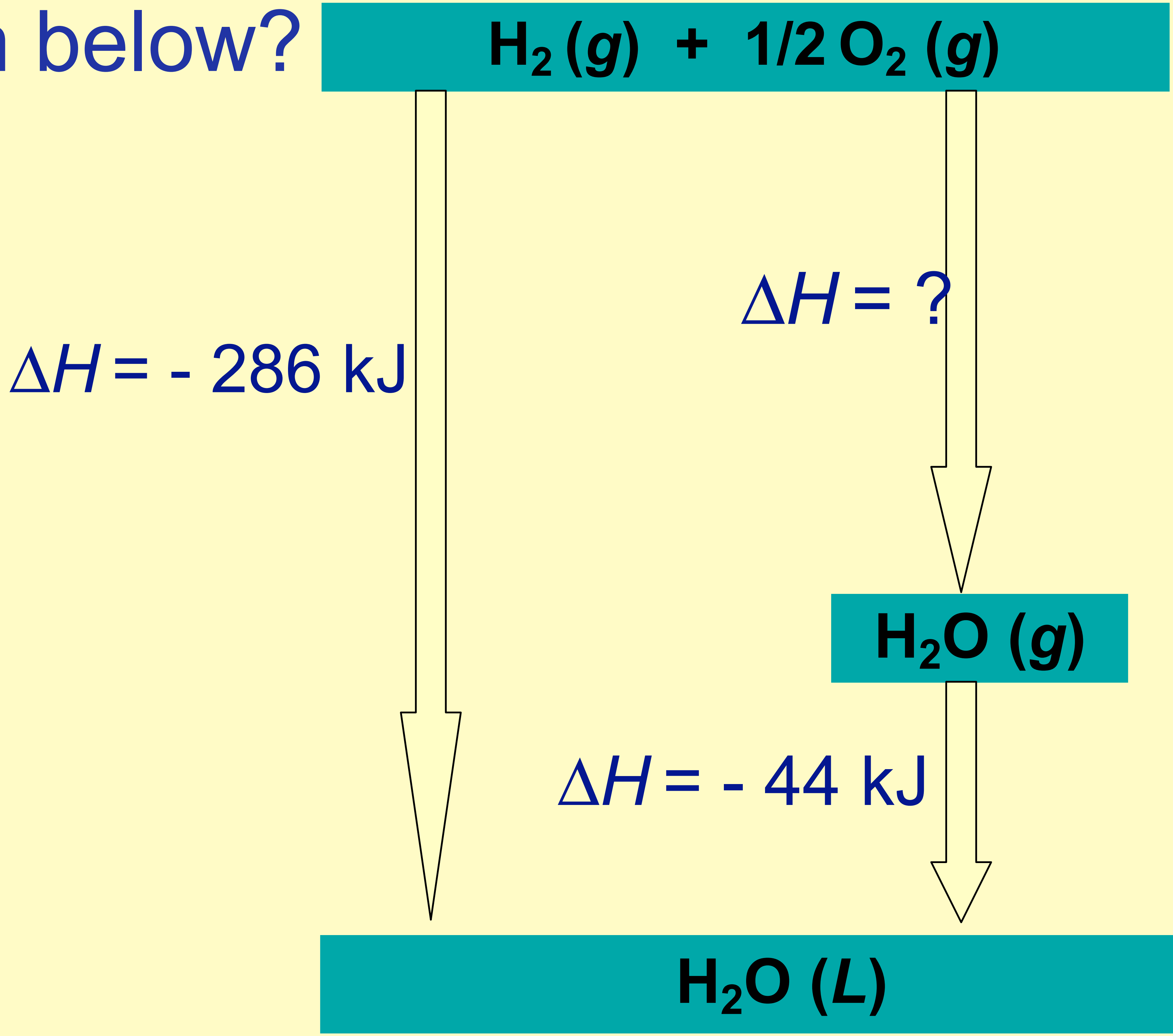
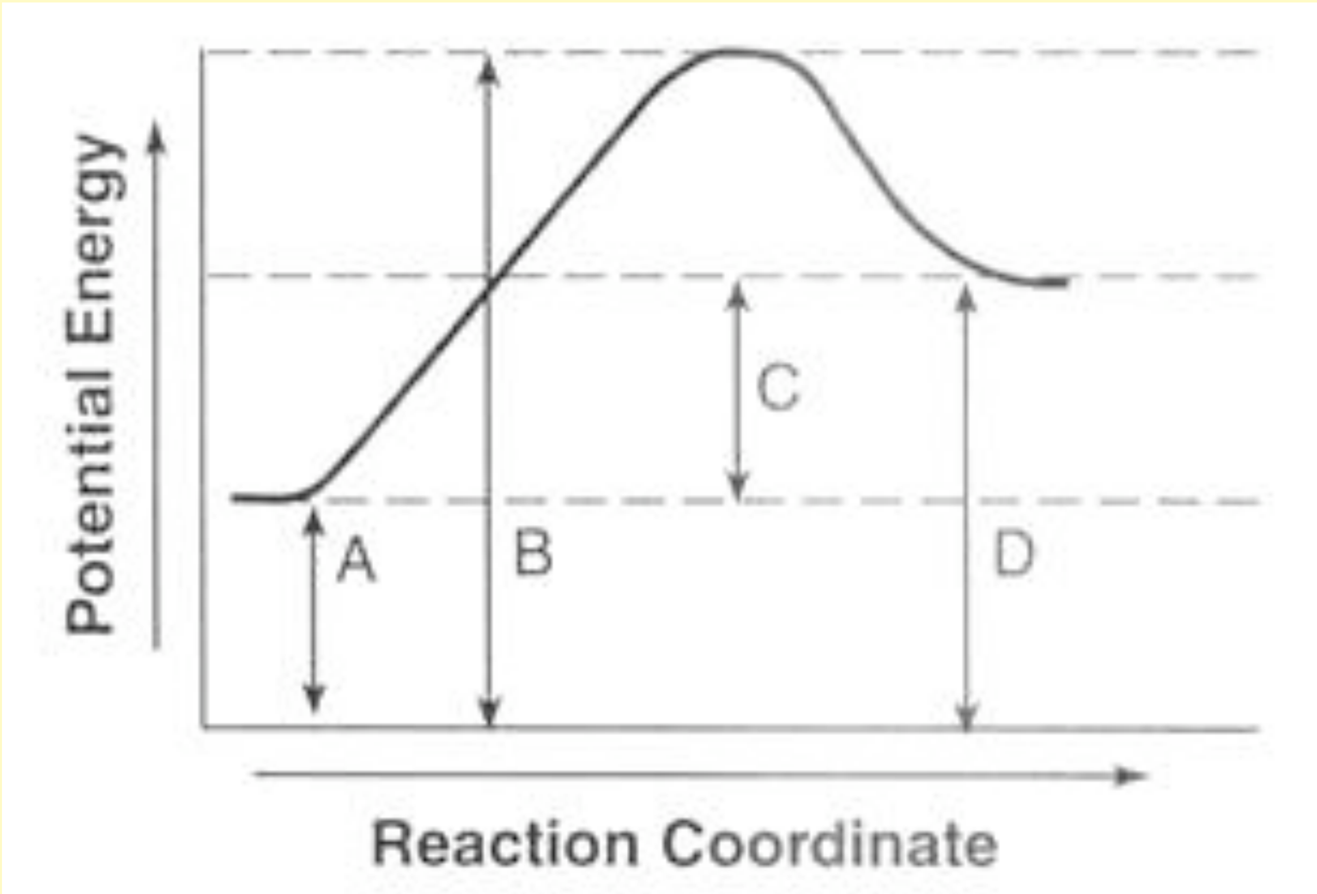


In a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is defined as

1. activation energy
2. ionization energy
3. heat of vaporization
4. heat of reaction
5. kinetic energy
6. lattice energy



5

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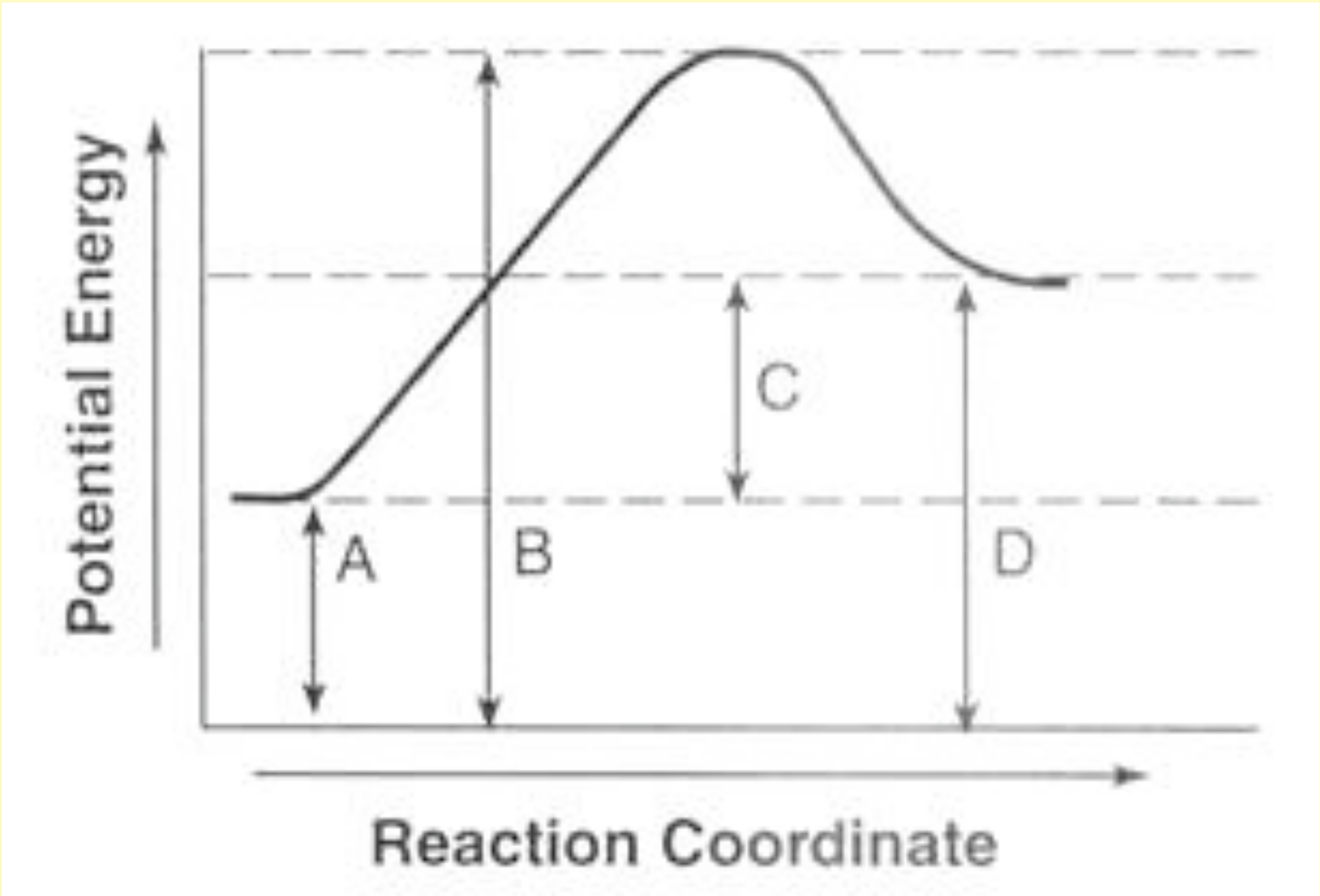
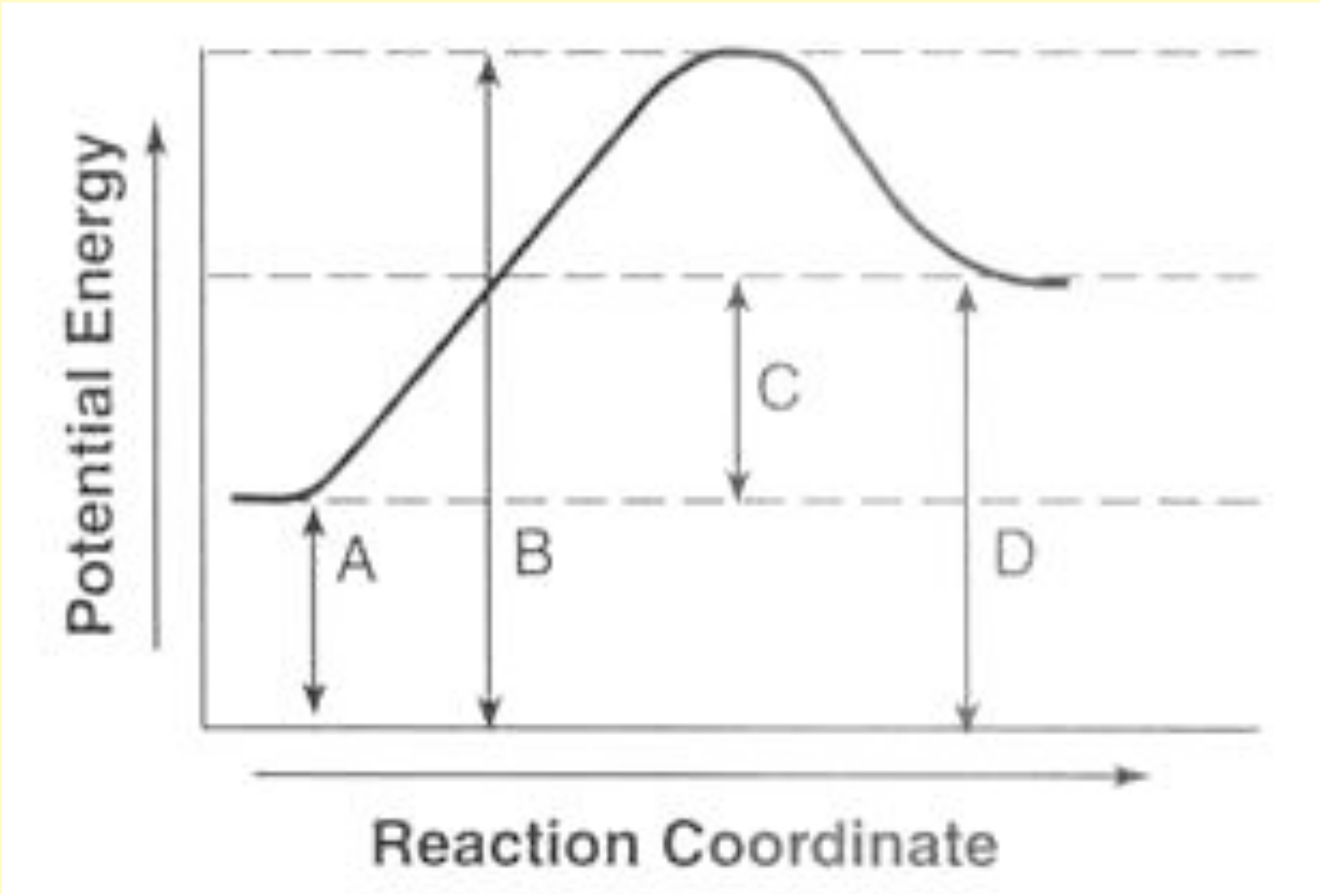


Which letter in the potential energy diagram shown below, represents the heat of the reaction, ΔH?

1. A
2. B
3. C
4. D



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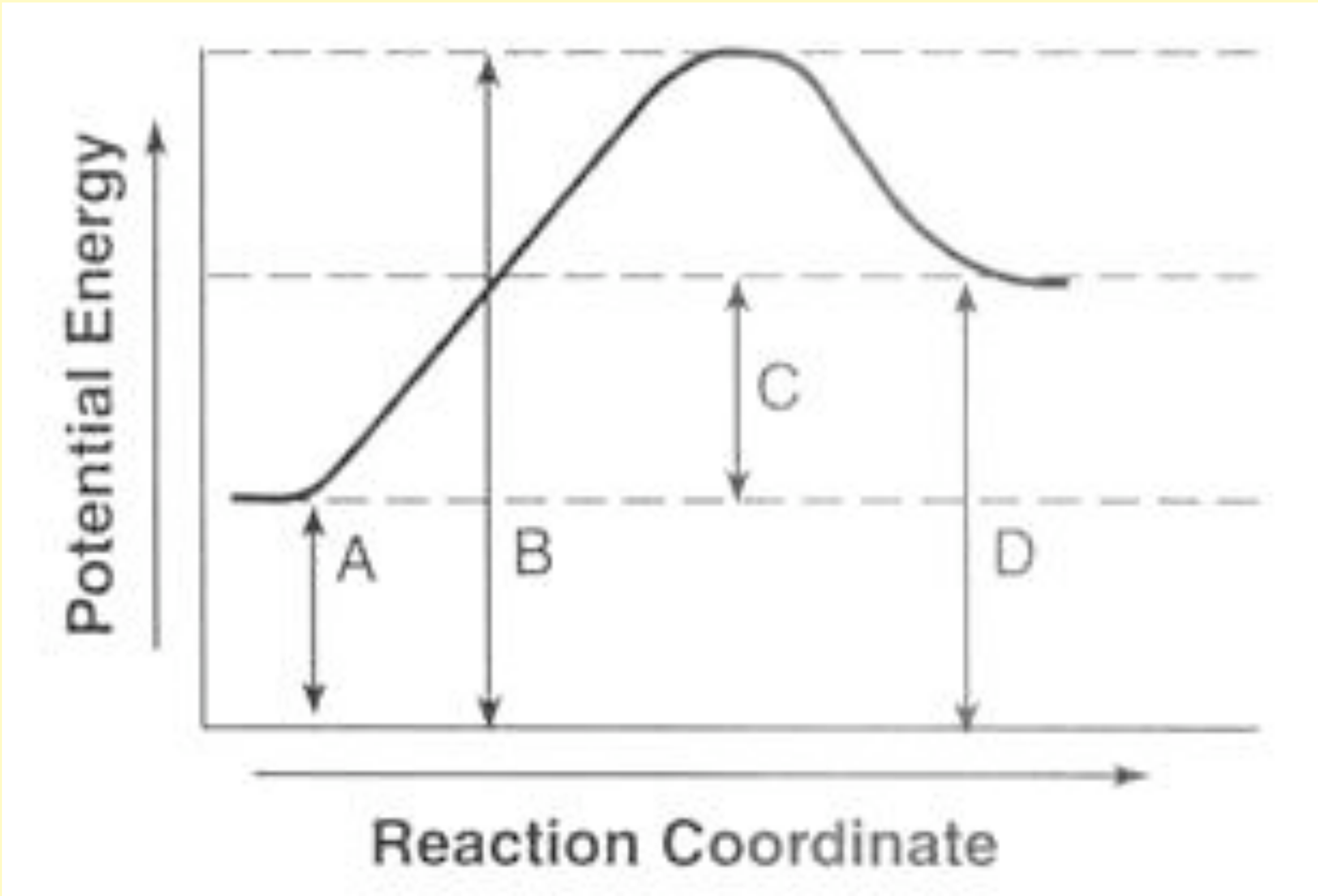
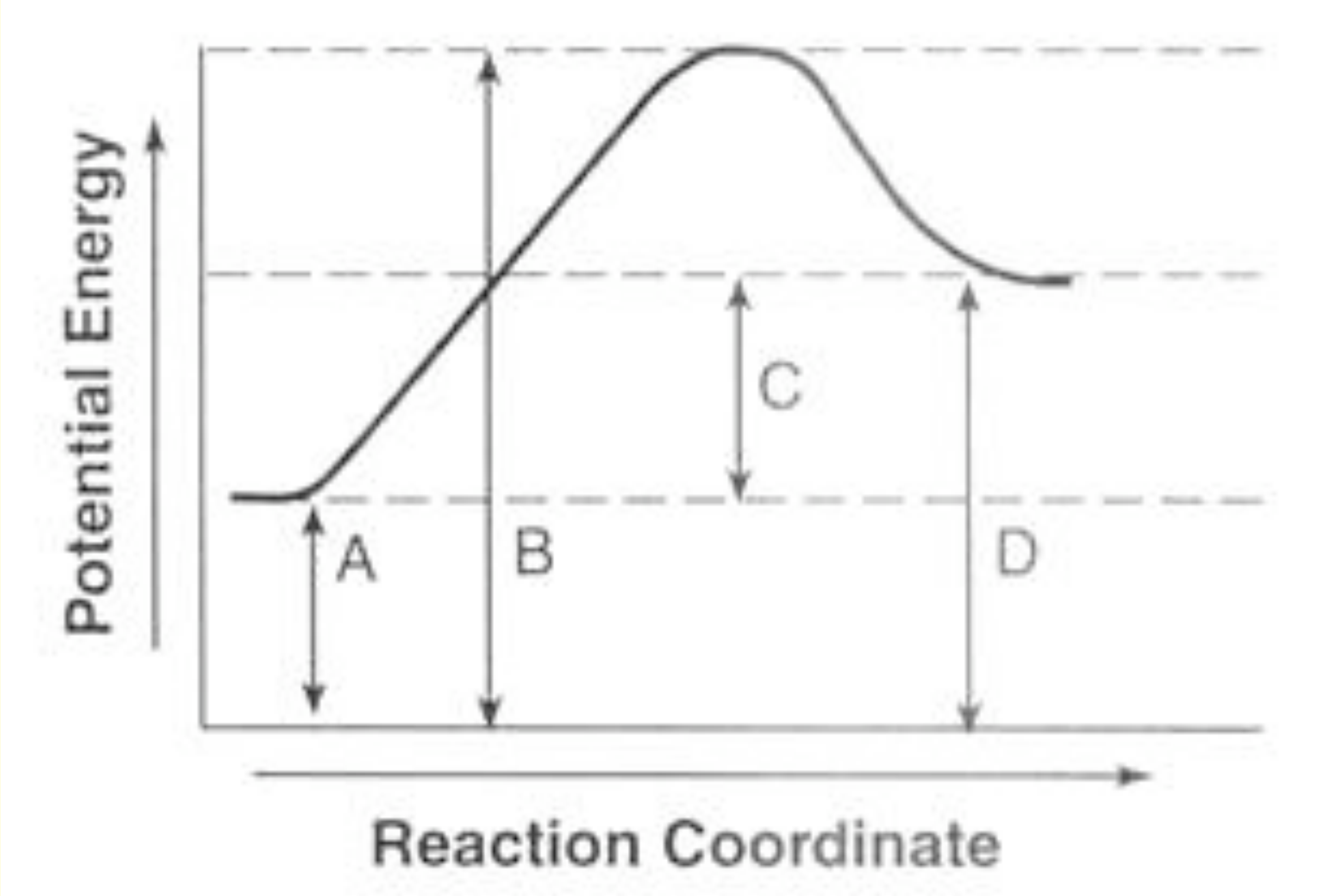


The reaction represented by this graph

1. is exothermic
2. is endothermic
3. There is not enough information to determine the energetics of this reaction.



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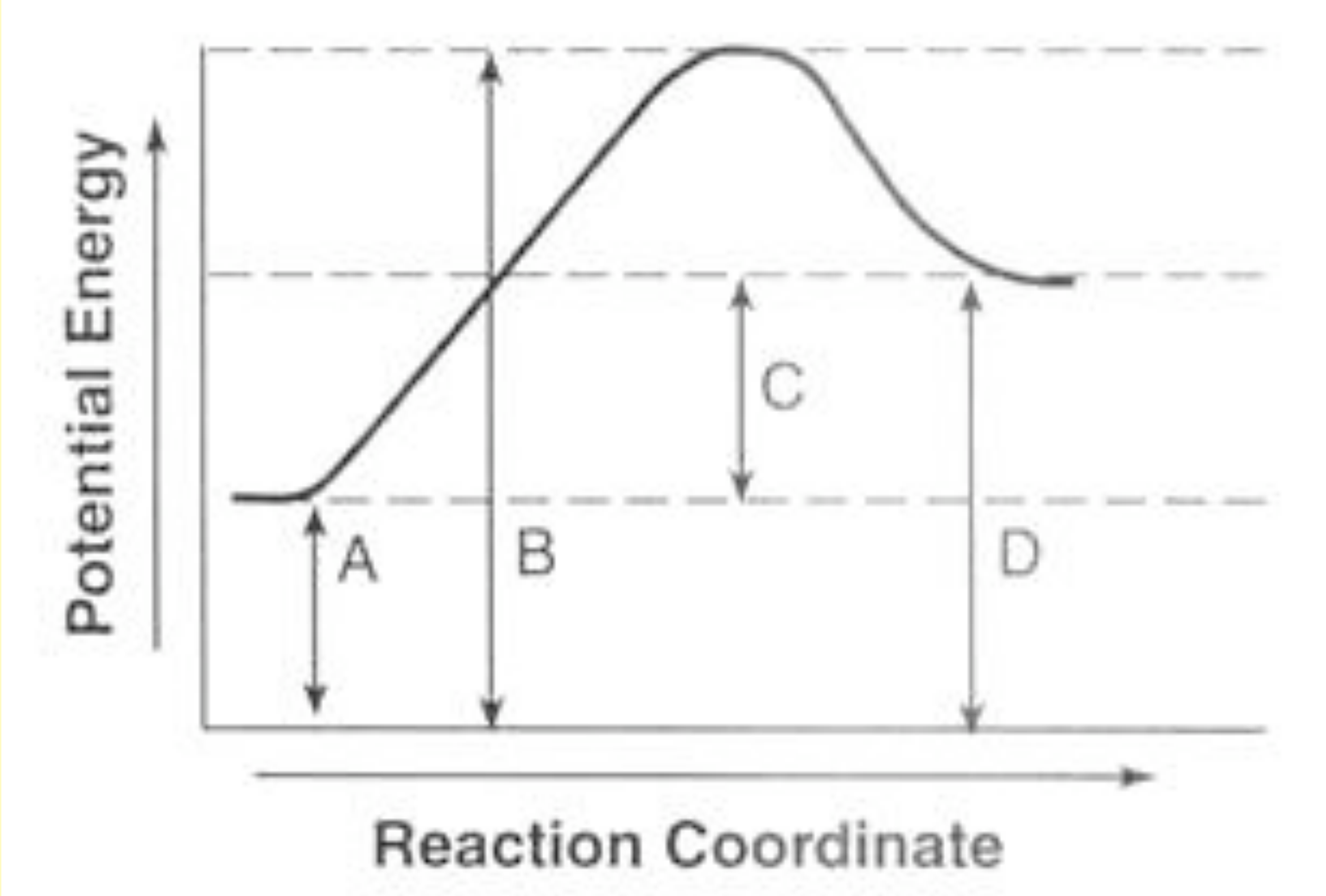

Bond breaking

1. is exothermic
2. is endothermic
3. depends on the reaction

Bond breaking

1. is exothermic
2. is *always* endothermic
3. depends on the reaction

- A chemical bond is a stable arrangement of electrons shared between the bonded atoms. Therefore a bond cannot be broken without the input of energy.

If bond breaking is endothermic, bond forming

1. is exothermic
2. is endothermic
3. depends on the reaction

If bond breaking is endothermic, bond forming

1. is exothermic
2. is endothermic
3. depends on the reaction

- When a chemical reaction occurs, bonds must be broken, and other bonds must form.
- The heat of the reaction is the net result of energy in (for bonds breaking) and energy out (for bonds forming.)

Using bond energies to estimate ΔH_{rx}

Use bond energy values to estimate the ΔH for $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(g)}$

1. Take an inventory of the bonds breaking (endothermic) and look up bond energy values.
2. Take an inventory of the bonds forming (exothermic) and look up bond energy values.
3. bonds breaking - bonds forming = ΔH

Using bond energies to estimate ΔH_{rx} Use bond energy values to estimate the ΔH for $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(g)}$

- Take an inventory of the bonds breaking and bonds forming
- H-H + ½(O=O) - 2(H-O)
- [436 + ½(495)] - [2(463)] = -242 kJ
- If you look up the heat of formation, ΔH^o_f for this reaction, you'll get
  - ΔH^o_f = -241.82 kJ/mol....nearly the same

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Use the bond energies to estimate ΔH_{comb} for the burning of propane.

1. Take an inventory of the bonds breaking (endothermic) and look up bond dissociation energy values.
2. Take an inventory of the bonds forming (exothermic) and look up bond dissociation energy values.
3. bonds breaking - bonds forming = ΔH
   - bond dissociation values of reactants - bond dissociation values of the products.

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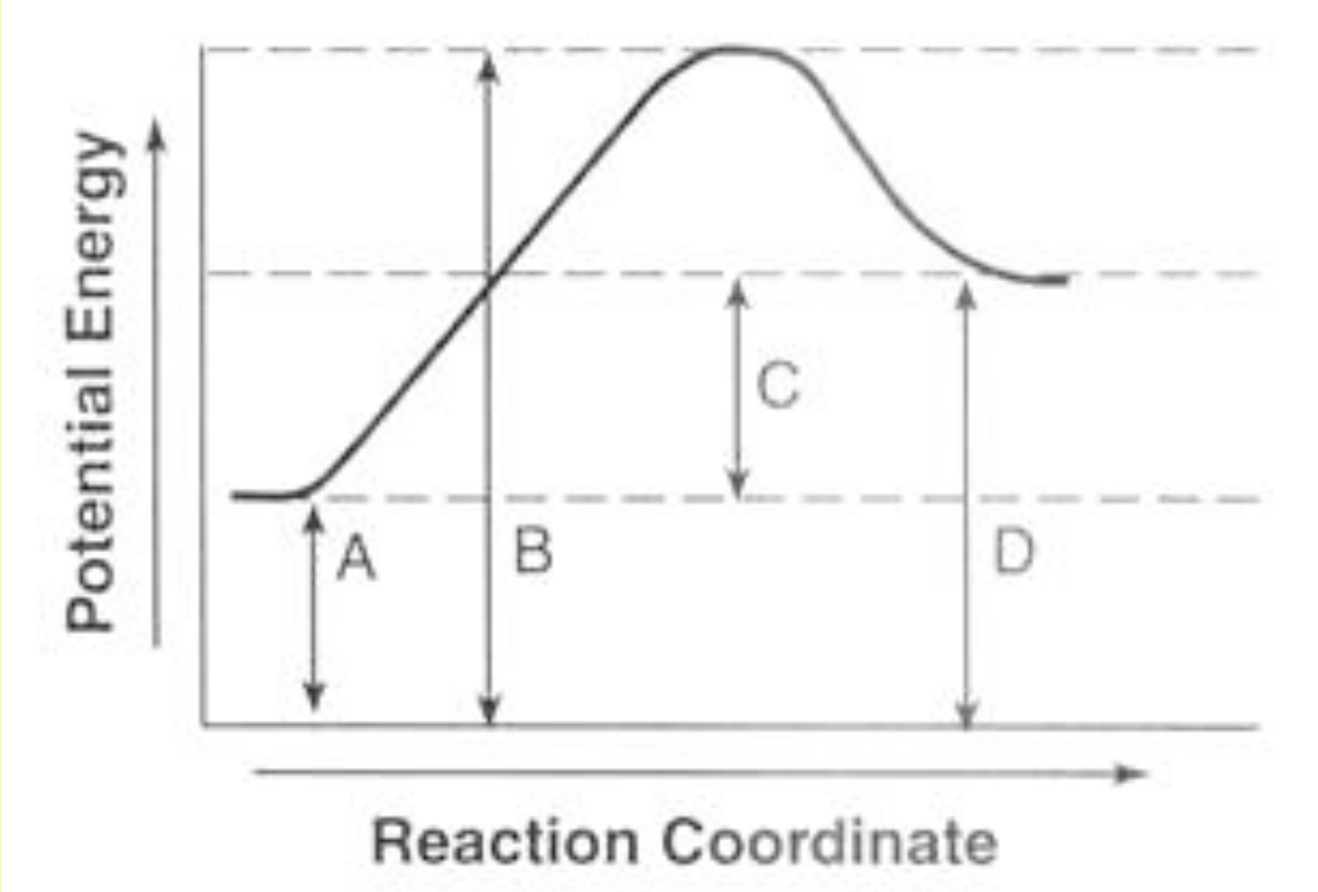
Use the bond energies to estimate ΔH_{comb} for the burning of propane.

1. $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$
2. bonds breaking
   - 2x C-C(348) + 8x C-H(413) + 5x O=O(495)
3. bonds forming
   - 6x C=O(799) + 8x O-H(463)
4. breaking - forming using bond energy values
   - ΔH_{comb} = -2,023 kJ/mol propane
5. calculate ΔH_{comb} using ΔH^o_f values
   - $\Delta H_{rx} = \Sigma n\Delta H^o_{f\ products} - \Sigma n\Delta H^o_{f\ reactants}$
   - ΔH_{comb} = -2044kJ/mol propane....pretty close to the previous calc
   - What might be causing the difference?
     - the fact that bond dissociation values are averages and not exact values for the molecules in the reaction. Bonds are affected by its neighbors.

The total bond dissociation energy of the products is __________ the bond dissociation energy of the reactants.

1. greater than
2. less than
3. the same as
4. none of the above, because this cannot be determined from this graph.



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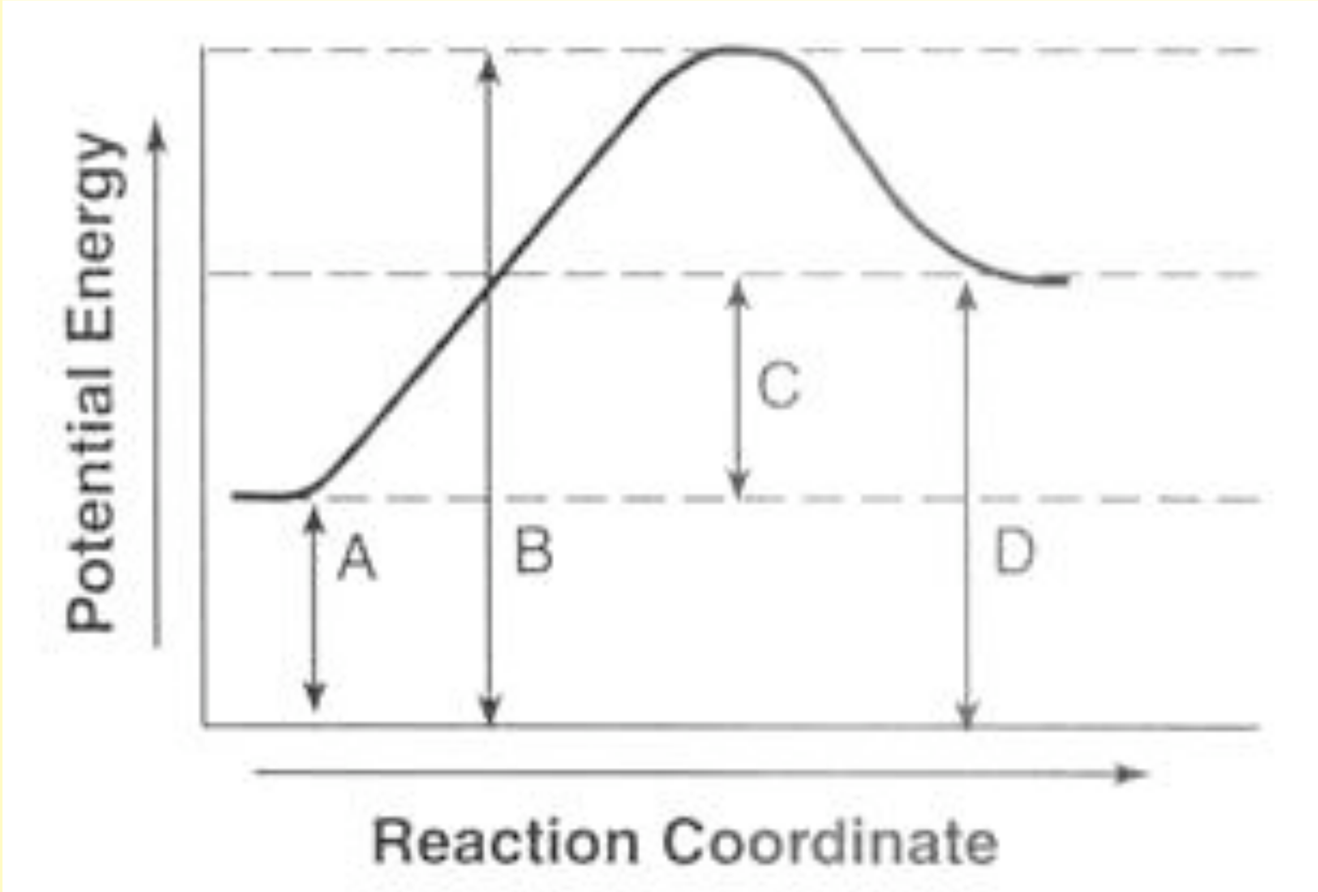

- We know this because there is less energy produced by the formation of the products than needed to break the reactants.

The heat of formation for gaseous benzene is represented below

$6C_{(s)} + 3H_{2(g)} \longrightarrow C_6H_{6(g)} \quad \Delta H^o_f = 83\ kJ$

The ΔH^o_f for liquid benzene is

1. greater positive value
2. smaller positive value
3. unable to determine

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The ΔH^o_f for liquid benzene is

1. greater positive value
2. smaller positive value
   - You know that gas → liquid is exothermic, so adding ΔH - to the ΔH above, will make it a smaller positive value.
3. unable to determine

22

Consider the following thermochemical equation:

$2H_{2(s)} + O_{2(g)} \rightarrow 2H_2O_{(L)} + 570\ kJ$

The ΔH^o_f for liquid water is

1. $(570)^2$
2. $(570)^{1/2}$
3. -570
4. +570
5. -285
6. +285

Consider the following thermochemical equation:

$2H_{2(s)} + O_{2(g)} \rightarrow 2H_2O_{(L)} + 570\ kJ$

The ΔH^o_f for liquid water is

1. $(570)^2$
2. $(570)^{½}$
3. -570
4. +570
5. -285

- When you take the thermochemical value out of the equation above, because it is exothermic, you need to represent it as negative.
- In addition, ΔH^of values are always per mole of twhatever is being formed from its elements.

6. +285

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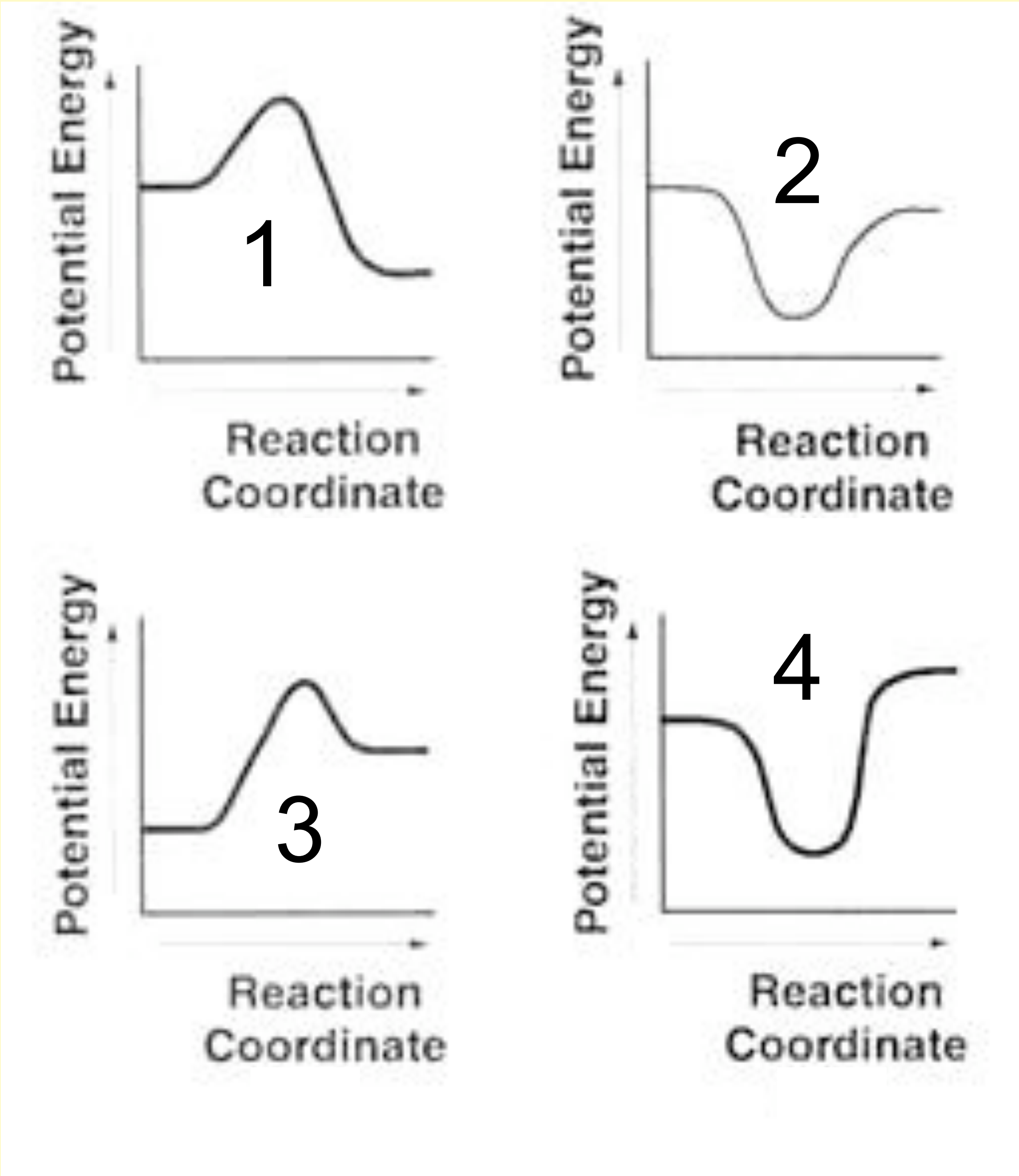
Which energy diagram below best represents the formation of liquid water?

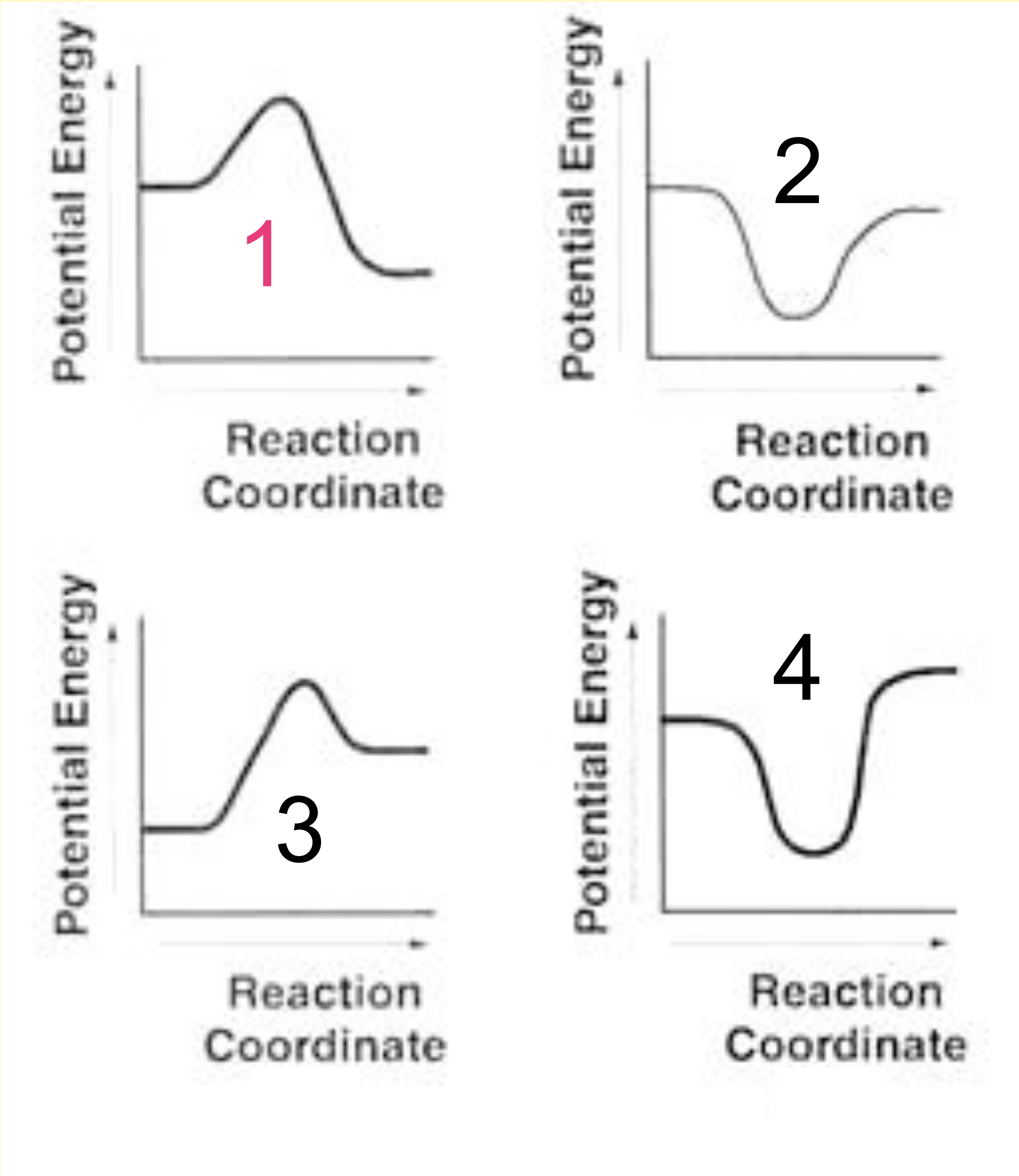
5. None of the choices are valid.



Which energy diagram below best represents the formation of liquid water?

5. None of the choices are valid.

- since we learned in the last slide that the formation of liquid water is exothermic.



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Use your Thermodynamic Tables to calculate the ΔH for the process of vaporizing solid iodine, I_2

Input your numeric answer.

Use your Thermodynamic Tables to calculate the ΔH for the process of vaporizing solid iodine, I_2

$I_{2(s)} \longrightarrow I_{2(g)}$

$\Delta H_{vap} = \Sigma\Delta H^o_{f\ products} - \Sigma\Delta H^o_{f\ reactants}$

+62.25 kJ/mole - 0 kJ/mole

thus ΔH_{vap} = +62.25/mole $I_{2(s)}$

28

Temperature *(select all that apply)*

1. is a measure of activation energy
2. is average kinetic energy
3. is heat
4. tell us hotness vs coldness
5. is proportional to molecular velocity
6. tells us the direction that heat will flow

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30

Use your Thermo Tables, and the enthalpy for the reaction given below to calculate the ΔH^o_f for gaseous propanol.

$C_3H_7OH_{(g)} + {}^9/_5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)}$

$\Delta H_{combustion}$ = -1870 kJ/mole alcohol

Enter a value rounded to the nearest whole number.

Use your Thermo Tables, and the enthalpy for the reaction given below to calculate the ΔH^o_f for gaseous propanol.

$C_3H_7OH_{(g)} + {}^9/_5 O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$

$\Delta H_{combustion}$ = -2061 kJ/mole

- $\Delta H_{rx} = \Sigma n \Delta H^o_{f\ products} - \Sigma n \Delta H^o_{f\ reactants}$
- [3(-393.5) + 4(-241.82)] - [(x) + (0)] = -2061 kJ
- x = H^o_f for $C_3H_7OH_{(g)}$ = -356 kJ

Which reaction best represents the ΔH^{o}_{f} for solid sodium nitrate?

1. $Na^{+1}_{(aq)} + NO_3{}^{-1}_{(aq)} \rightarrow NaNO_{3(aq)}$
2. $Na^{+1}_{(g)} + NO_{3(g)} \rightarrow NaNO_{3(s)}$
3. $Na_{(s)} + NO_{3(s)} \rightarrow NaNO_{3(s)}$
4. $Na_{(s)} + N_{2(g)} + 3O_{2(g)} \rightarrow 2NaNO_{3(s)}$
5. $Na_{(s)} + \frac{1}{2}N_{2(g)} + {}^{3}/_{2}O_{2(g)} \rightarrow NaNO_{3(s)}$

33

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5. $Na_{(s)} + \frac{1}{2}N_{2(g)} + {}^{3}/{}_{2}O_{2(g)} \rightarrow NaNO_{3(s)}$

34

$2B_{(s)} + 3H_{2(g)} \rightarrow B_2H_{6(g)}$

Use the reactions below to determine the ΔH for formation of diborane shown above.

$2B_{(s)} + {}^3/_2O_{2(g)} \rightarrow B_2O_{3(s)}$ ΔH=a

$B_2H_{6(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O_{(g)}$ ΔH=b

$H_{2(g)} + ½O_{2(g)} \rightarrow H_2O_{(L)}$ ΔH=c

$H_2O_{(L)} \rightarrow H_2O_{(g)}$ ΔH=d

1. a+b+c+d
2. a-b+3c
3. a-b+3c+3d
4. b-a+c^3
5. b-a+3d
6. b-a-3c-3d
7. some other sum not listed above

35

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$B_2H_{6(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O_{(g)}$ ΔH=b

$H_{2(g)} + ½O_{2(g)} \rightarrow H_2O_{(L)}$ ΔH=c

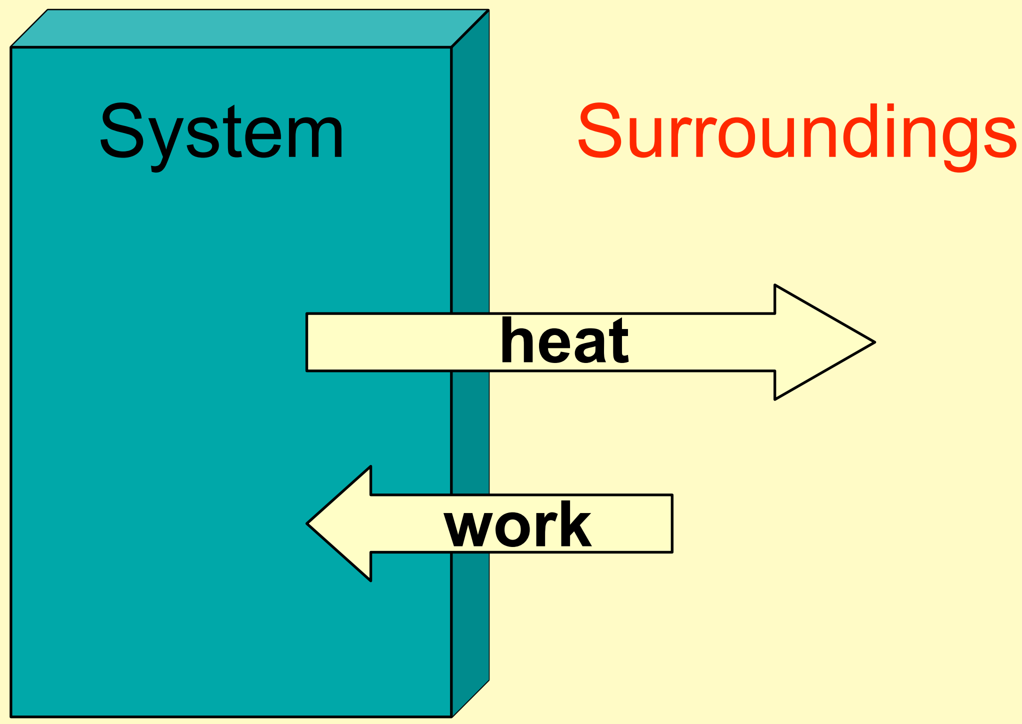
$H_2O_{(L)} \rightarrow H_2O_{(g)}$ ΔH=d

1. a+b+c+d
2. a-b+3c
3. a-b+3c+3d
4. b-a+c^3
5. b-a+3d
6. b-a-3c-3d
7. some other sum not listed above

36

Which accurately describes the diagram below? *(Choose all that apply.)*

1. $\Delta H < 0$
2. "exo-work-ic"
3. Endothermic
4. $q = w$
5. ΔE of system decreases
6. The system must be at a higher temperature than the surroundings.



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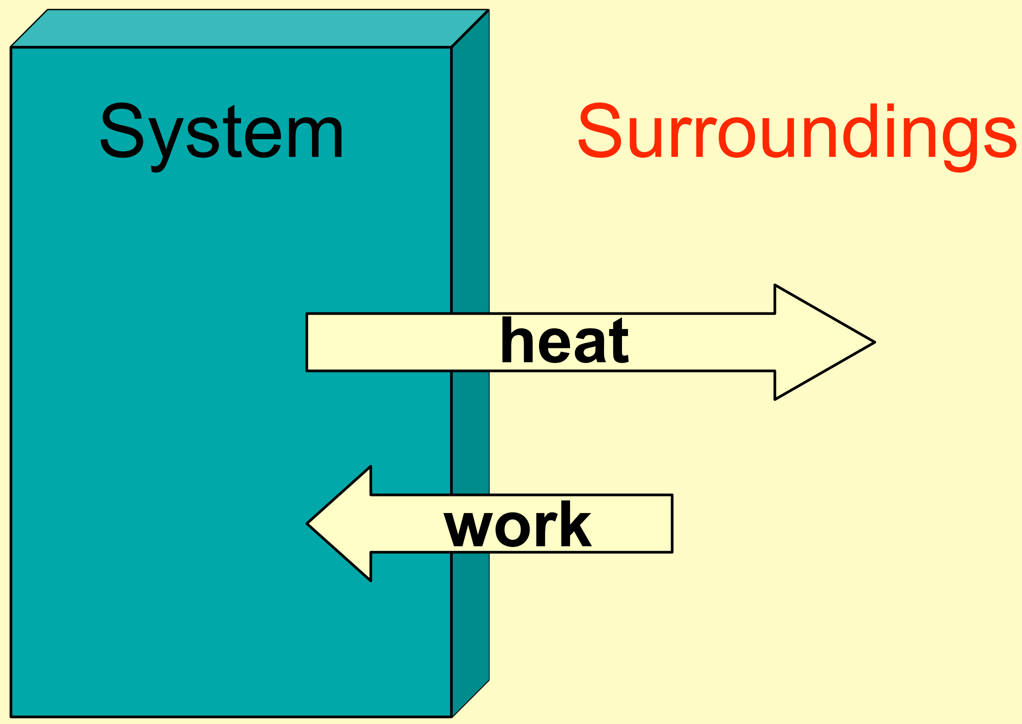
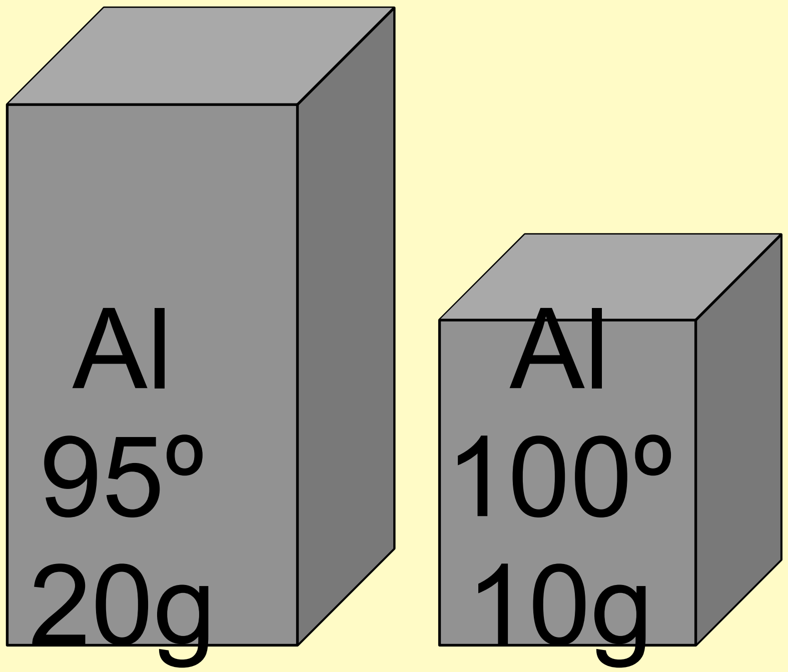


Which block is hotter?

1. Bigger block
2. Smaller block
3. Same



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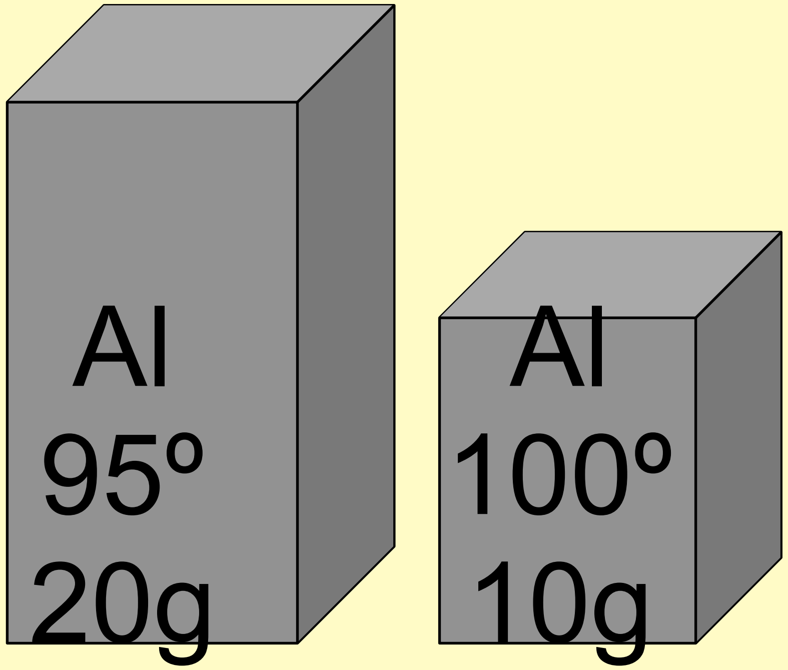

Which block contains more heat?

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2. Smaller block
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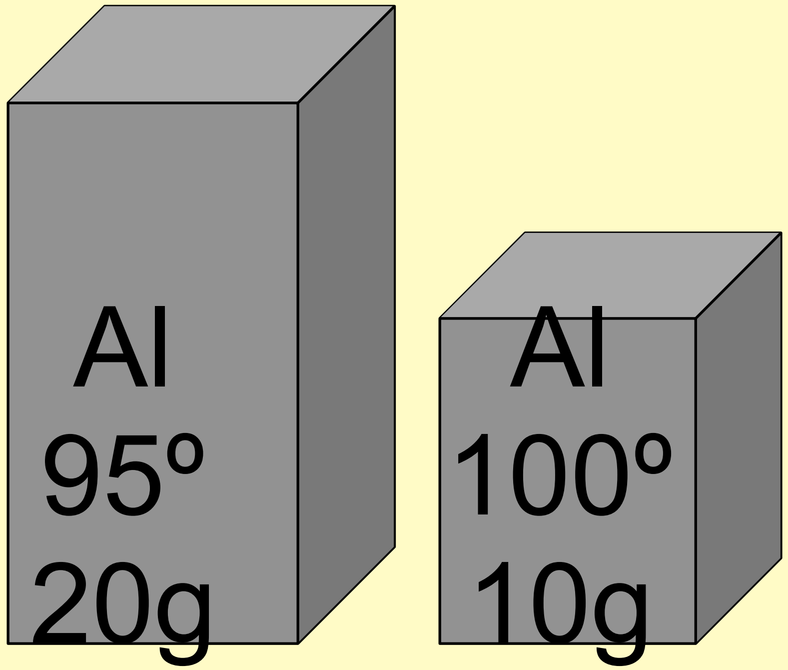

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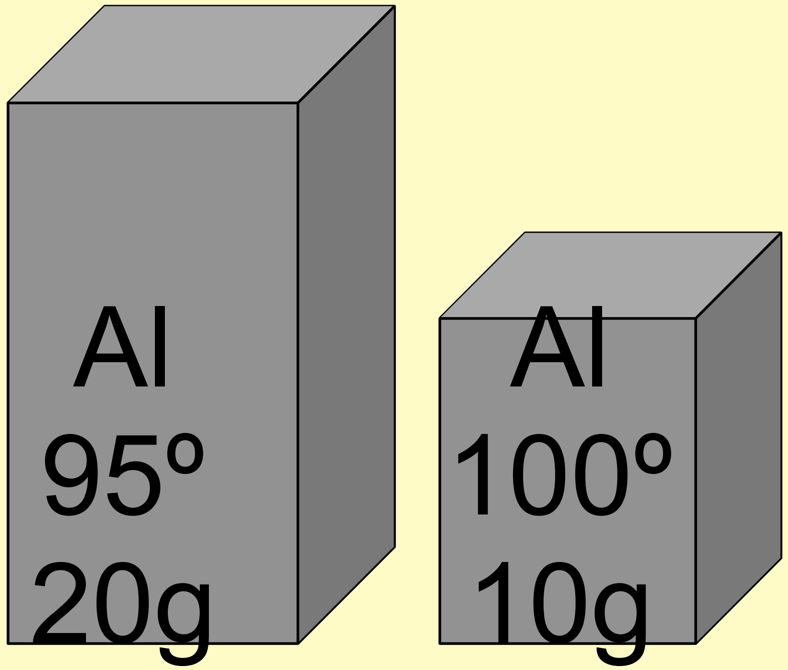
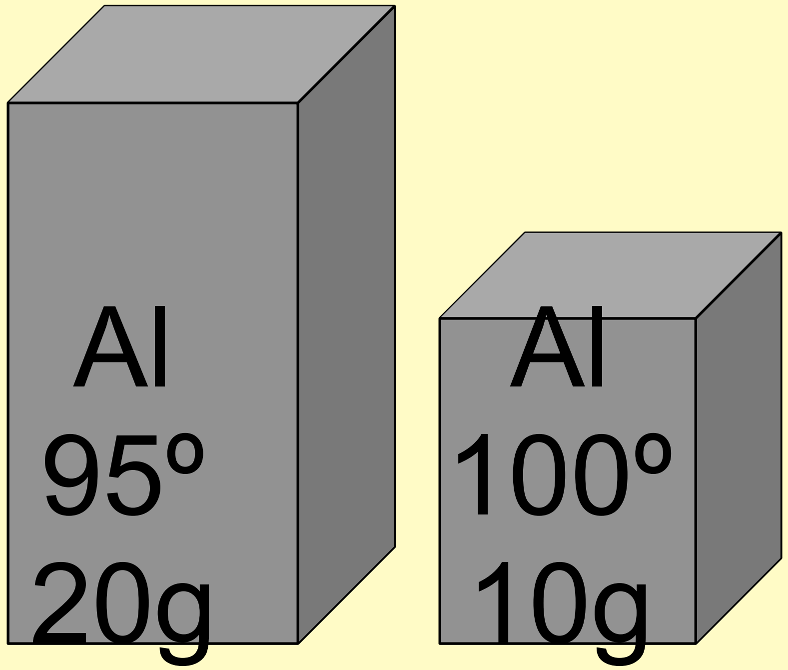


42

Which block has the higher C_p?

1. Bigger block
2. Smaller block
3. Same



43

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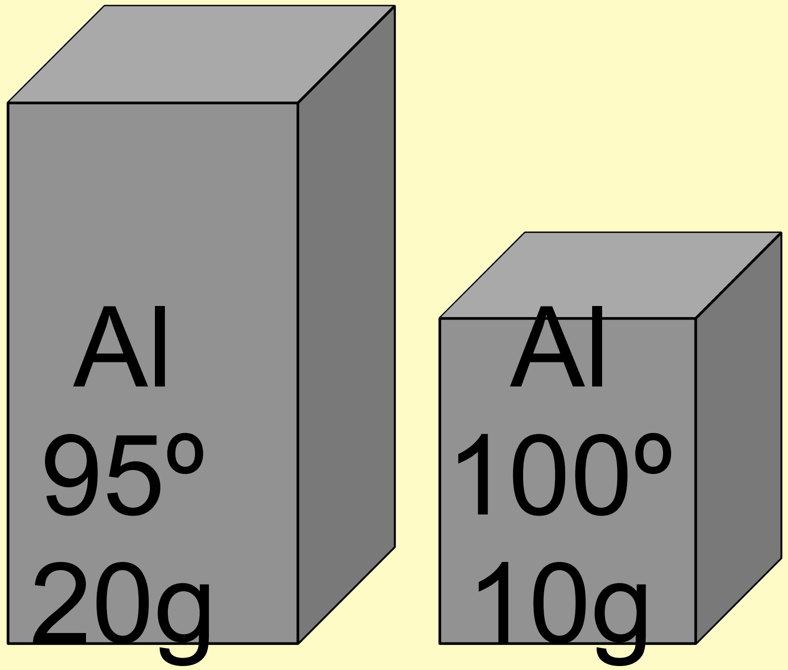

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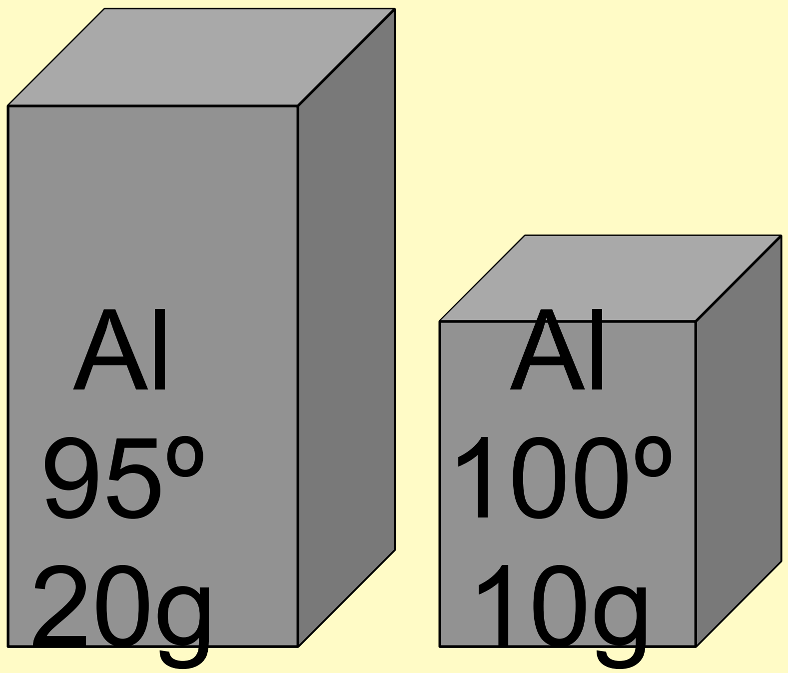
Which block has the higher specific heat capacity, c?

1. Bigger block
2. Smaller block
3. Same



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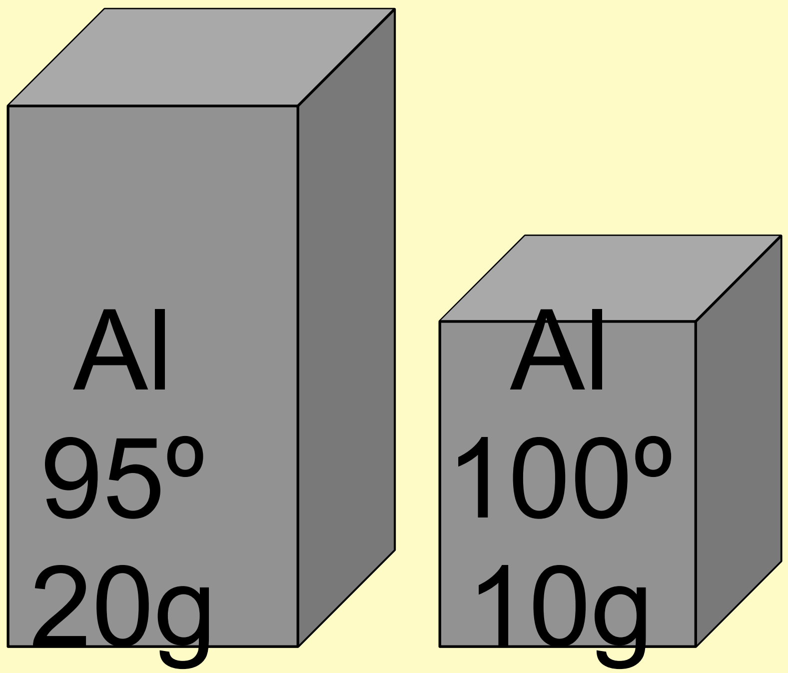
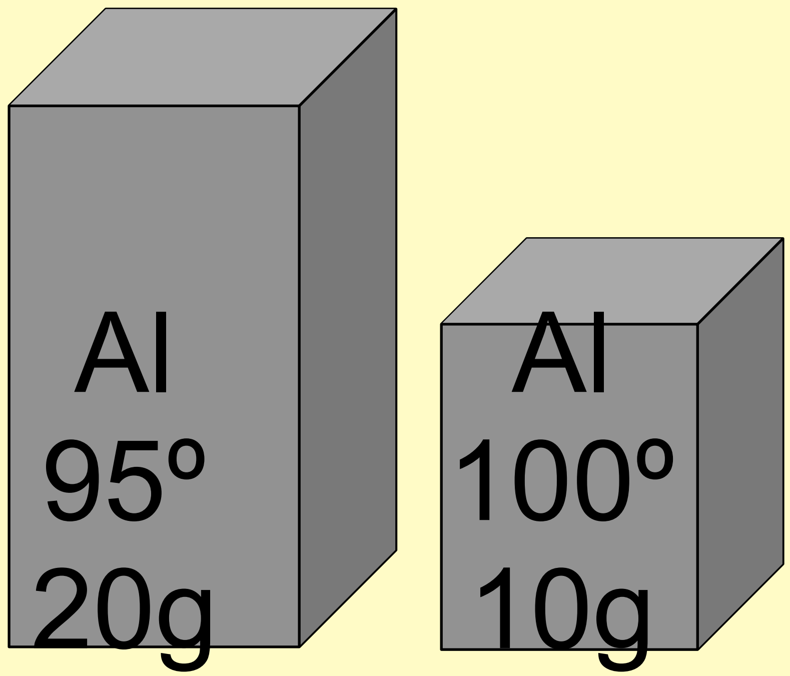


If these two blocks were allowed to come to thermal equilibrium together, would the final temp

1. Be closer to 95º
2. Be closer to 100º
3. Be 97.5º
4. Be impossible to know without more information.



If these two blocks were allowed to come to thermal equilibrium together, would the final temp

1. Be closer to 95º
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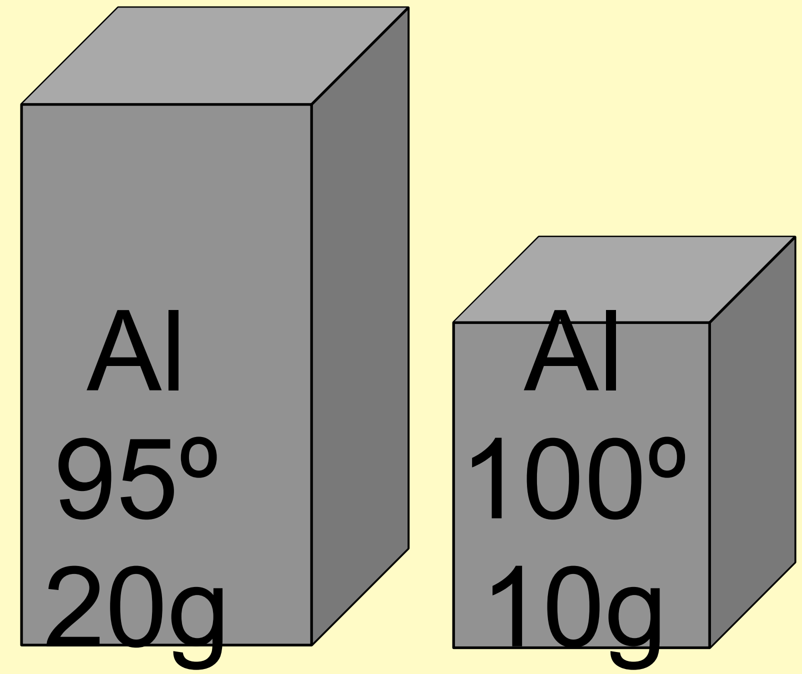
4. Be impossible to know without more information.

- Write out an equation that would allow you to solve for the final temperature.



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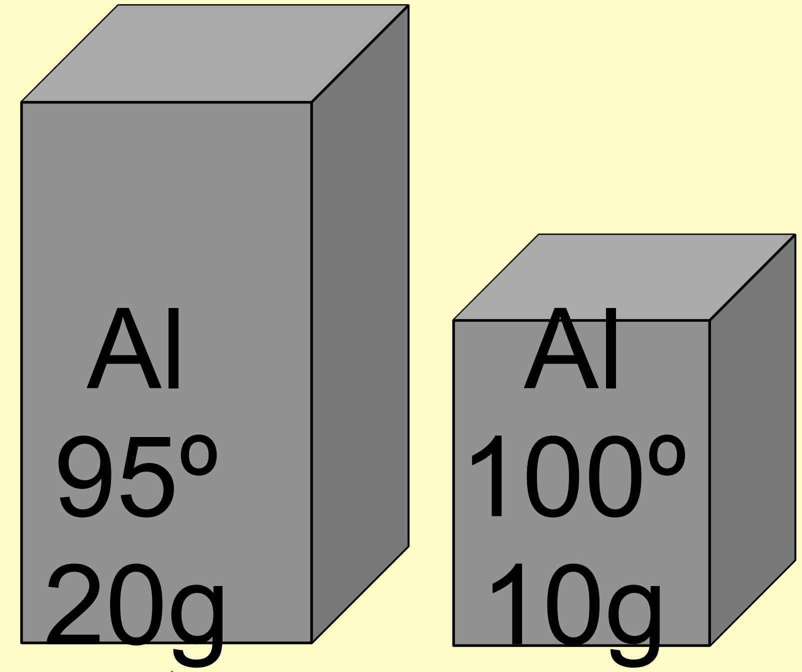

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2. Be closer to 100º
3. Be 97.5º
4. Be impossible to know without more information.

- Write out an equation that would allow you to solve for the final temperature.
- $20(x-95) = 10(100-x)$
- $x = 96.7º$

49

The unit label on specific heat capacity is

1. J
2. J/g
3. kJ/mole
4. J/ºC
5. J/gºC

The unit label on specific heat capacity is

1. J
2. J/g
3. kJ/mole
4. J/ºC
5. J/gºC

51

The unit label on heat capacity is

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5. J/gºC

The unit label on heat capacity is

1. J
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3. kJ/mole
4. J/ºC
5. J/gºC

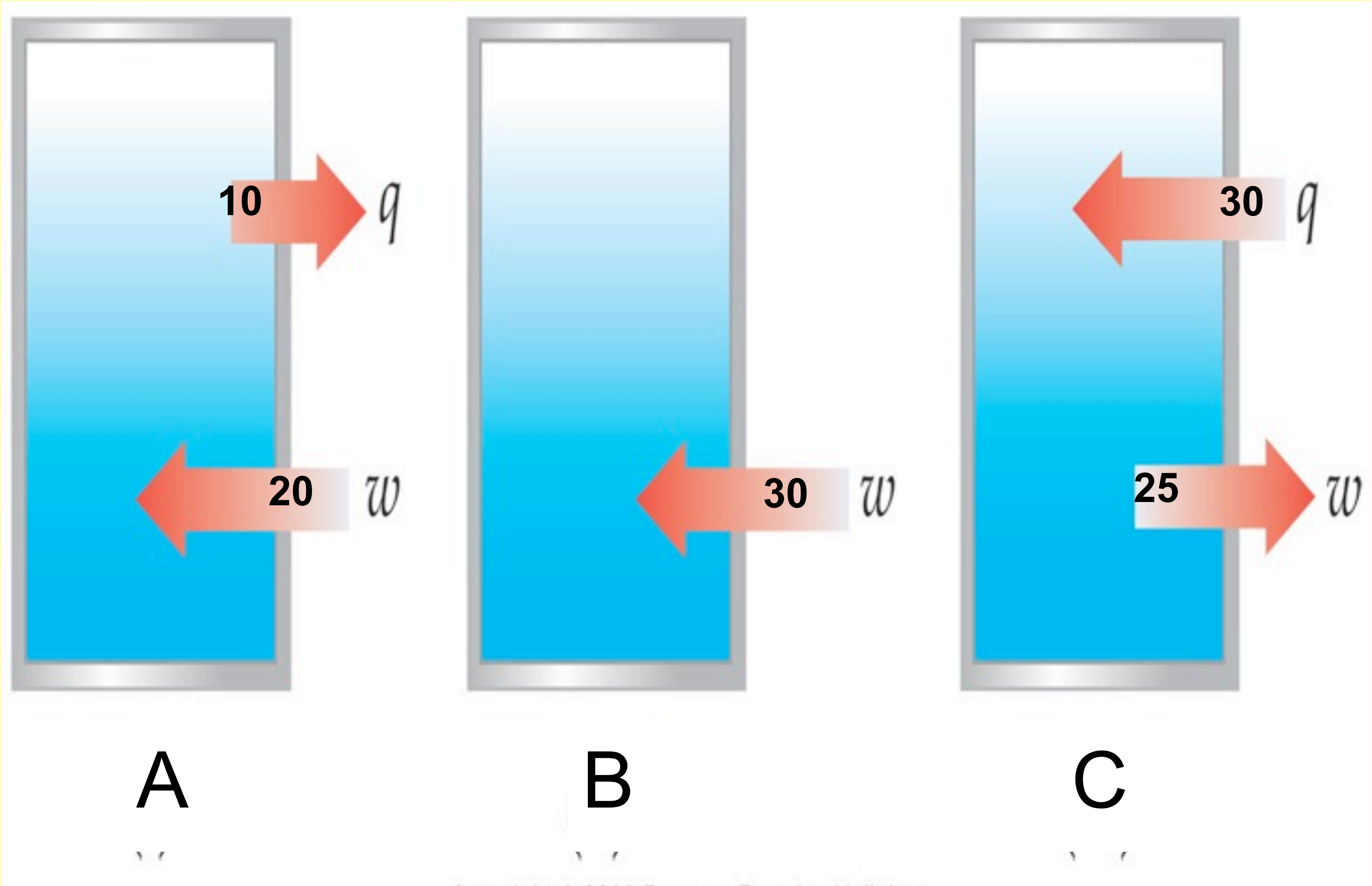
The unit label on ΔH^o_f is

1. kJ
2. kJ/mole
3. kJ/mole°C
4. J/g
5. J/°C
6. J/g°C

The unit label on ΔH^o_f is

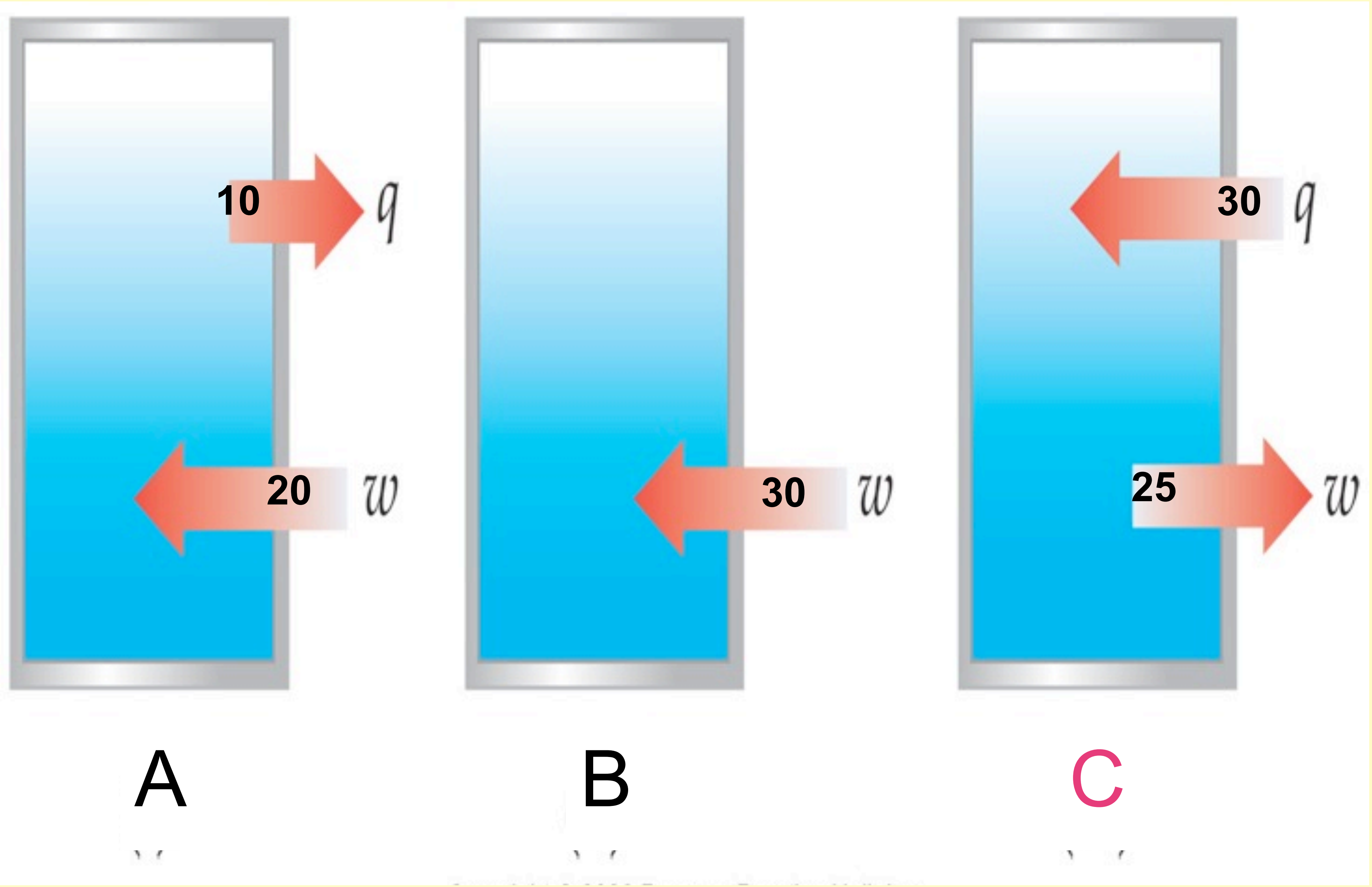
1. kJ
2. kJ/mole
3. kJ/mole°C
4. J/g
5. J/°C
6. J/g°C

Which diagram(s) below is(are) endothermic?

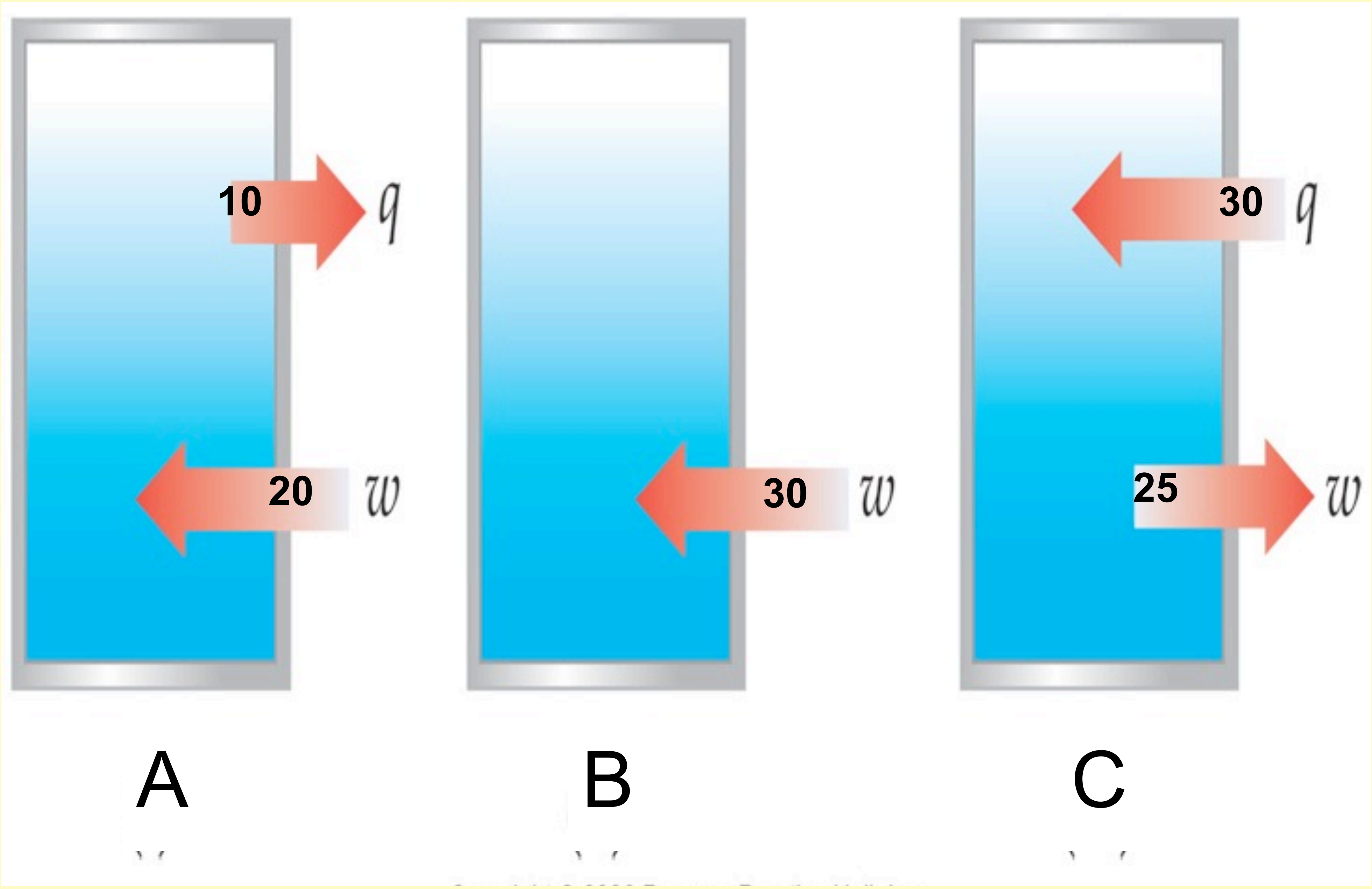


Which diagram(s) below is(are) endothermic?

Only C

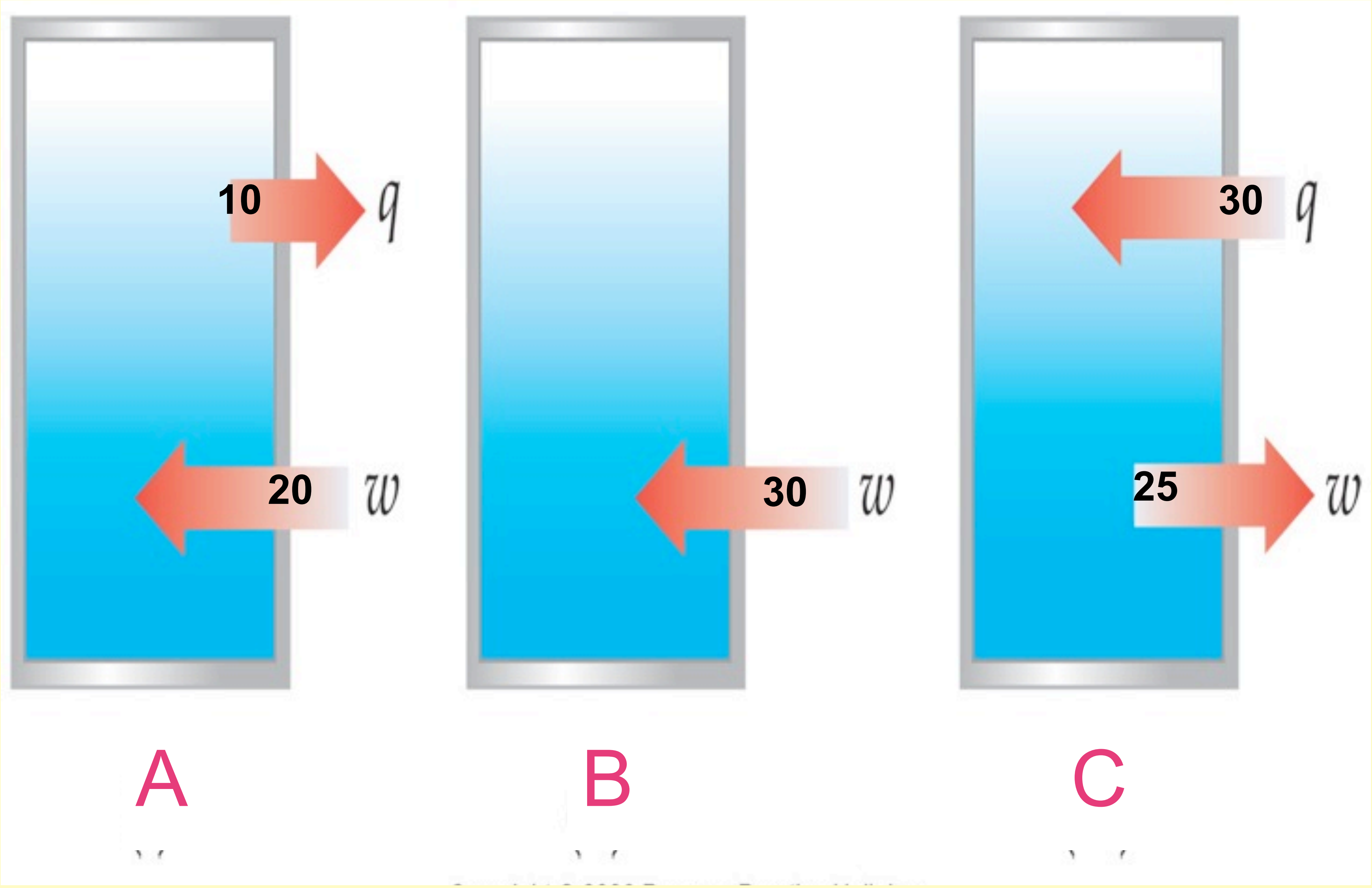


In which diagram(s) does(do) the internal energy increase?



In which diagram(s) does(do) the internal energy increase?

All of them



$N_{2(g)} + 2O_{2(g)} \rightarrow N_2O_{4(g)}$ For this reaction as it occurs at constant pressure, ΔH is approximately equal to

1. ΔE + RT
2. ΔE - RT
3. ΔE + 2RT
4. ΔE - 2RT
5. ΔE + 3RT
6. ΔE - 3RT
7. ΔE + 4RT
8. ΔE - 4RT

$w = -P\Delta V$

$\Delta E = q + w$

$\Delta H = q$ (for reaction that occurs at constant pressure)

So $\Delta E - w = q$

thus $\Delta E + P\Delta V = q$

thus $\Delta E + P\Delta V = \Delta H$

and since $P\Delta V = \Delta nRT$

finally $\Delta E + \Delta RT = \Delta H$

60

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2. ΔE - RT
3. ΔE + 2RT
4. ΔE - 2RT
5. ΔE + 3RT
6. ΔE - 3RT
7. ΔE + 4RT
8. ΔE - 4RT

Using $\Delta E + \Delta RT = \Delta H$

there is a change in moles from 3 to 1

Which metal will undergo the greatest temperature change if an equal amount of heat is added to each?

1. Fe, c = 0.45 J/g K
2. Al, c = 0.90 J/g K
3. Cu, c = 0.38 J/g K
4. Pb, c = 0.13 J/g K
5. Sn, c = 0.22 J/g K

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Which metal will undergo the greatest temperature change if an equal amount of heat is added to each?

1. Fe, *SHC* = 0.45 J/g K
2. Al, *SHC* = 0.90 J/g K
3. Cu, *SHC* = 0.38 J/g K
4. Pb, *SHC* = 0.13 J/g K

- Materials with low specifi heat are easier to change their temperatures.

5. Sn, *SHC* = 0.22 J/g K

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