## Adopted Levels

S(p)=−1376 *20*

S(p): From $S_p$=−$E_{c.m.}$($^{17}$Ne+p) for the $^{18}Na_{g.s.}$, where $E_{c.m.}$($^{17}$Ne+p) is deduced as the weighted average of 1.27 MeV *17* (2004Ze05), 1.23 MeV *15* (2012Mu05) and 1.38 MeV *2* (2025Ni11). This compares with $S_p$=−1250 keV *90* given in (2021Wa16: AME-2020).

Evaluator deduced a mass excess of ΔM=25166 keV *20* for the $^{18}Na_{g.s.}$ from the weighted average of ΔM=25.04 MeV *17* (2004Ze05), 25.02 MeV *15* (2012Mu05) and 25.17 MeV *2* (2025Ni11).

The discovery of $^{18}$Na is credited to (2004Ze05: $^{9}$Be($^{20}$Mg,$^{18}$Na→$^{17}$Ne+p)). See also (2012Th10). All experimental evidence is consistent with the scenario that all observed levels of $^{18}$Na proton decay 100% to levels in $^{17}$Ne.

*Theoretical Studies*:

J. Jänecke, Nucl. Phys. 61 (1965) 383: Predicted that $^{18}$Na is unbound with respect to proton emission by 1.6 MeV.

1966Ke16: Calculated the mass excess of $^{18}$Na to be 25.4 MeV *4* using the isobaric mass formula.

1976Ja23: Calculated mass excess of $^{18}$Na to be ΔM=25.57 MeV. This value is compiled by the (1976Wa18) atomic mass evaluation.

1978Gu10: Calculated mass excess ΔM($^{18}$Na)=25.771 MeV, with an overall accuracy of 150 keV, using the isobaric multiplet mass equation (IMME). The deduced value agrees with that estimated by Jänecke−Garvey−Kelson (1976Ja23, 1976Wa18).

1983AnZQ, 1984An18, 1986An07: Deduced Coulomb energy using the IMME calculations and calculated mass excess ΔM($^{18}$Na)=25.319 MeV *22*. The uncertainty resulted from fitting the *b* coefficient of the IMME equation.

1988Ja08: Calculated mass excess using the Garvey-Kelson mass relation. Deduced ΔM=25.4 MeV *2*.

1988Pa14: Calculated mass excess for T(z)<0 nuclei using the IMME equation. Deduced ΔM=25.7 MeV *2*.

2004Ge02: Calculated binding energy, radii, deformation parameters, neutron and proton separation energies using deformed relativistic mean field calculations.

2008Qi04: Calculated energies, J, π, Q-values for proton resonances using a mean-field model.

2012Ko09: Calculated *rms* radii, *rms* radius of neutron and proton distributions, isovector shift of nuclear *rms* radii, bulk density, neutron skin. Direct variational method, extended Thomas-Fermi approximation. Comparison with experimental data.

2018Fo04: Analyzed and fitted mirror energy differences between $2s_{1/2}$, $1d_{5/2}$, and $1f_{7/2}$ single-particle states in neutron-excess nuclei and their proton-excess mirrors. Comparison with improved Kelson-Garvey (ImKG) model.

2022Zo01: Calculated S(p), S(2p), mass excesses for proton-rich systems, both inside and outside the proton drip line, in terms of mass relations for mirror nuclei, based on Weizsäcker mass formula. Comparison with available evaluated experimental data from AME-2020, and deduced root-mean-square deviations.

2024Ya25: Calculated positron energy, $T_{1/2}$. Comparison with available data.

2025Ya15: Analyzed available data; deduced $T_{1/2}$; the initial highest decay kinetic energy decreases straightly with respect to the atomic mass number for each of the sets of radioisotopes of the same element.

*Previous Evaluations*:

1972Aj02, 1978Aj03, 1983Aj01, 1987Aj02, 1995Ti07, and TUNL evaluation in 2015.

### $^{18}$Na Levels

Cross Reference (XREF) Flags

| | | | |
|---|---|---|---|
| A | $^{1}$H($^{17}$Ne,p):res | D | $^{9}$Be($^{20}$Mg,$^{18}$Na) at GSI |
| B | $^{9}$Be($^{17}$Ne,$^{18}$Na) | E | $^{9}$Be($^{20}$Mg,$^{18}$Na) at NSCL |
| C | $^{9}$Be($^{20}$Mg,$^{18}$Na) at GANIL | | |

| E(level)[a] | $J^{\pi}$ | Γ | XREF | Comments |
|---|---|---|---|---|
| 0[f] | (1$^{-}$) | <40 keV | CDE | %p=100 (2004Ze05,2012Mu05,2025Ni11)<br>Γ: From (2025Ni11).<br>Γ: See also Γ=0.48 MeV *14* (2004Ze05), Γ<0.2 MeV (2012Mu05) and $\Gamma_{p_0}$<1 keV and $\Gamma_{p_1}$<1 keV (2012As04).<br>$J^{\pi}$: From mirror analysis in (2004Ze05) and shell model analysis in (2012As04). |

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## Adopted Levels (continued)

### $^{18}$Na Levels (continued)

| E(level)[a] | J$^\pi$ | Γ | XREF | Comments |
|---|---|---|---|---|
| | | | | J$^\pi$=1$^-$ was suggested by (2025Ni11), who used a three-level Breit-Wigner analysis. It is unclear if the J$^\pi$ was a fit parameter in that study, or if they assumed the J$^\pi$ value from previous mirror/shell model analyses. We therefore, consider the assignment tentative.<br>Decays to $^{17}Ne_{g.s.}$+p. |
| 174[d] *21* | 2$^-$[b] | 5[c] keV *3* | AB DE | %p=100 (2012As04,2004Ze05,2023Ch22)<br>$\Gamma_{p0}$=5 keV *3* (2012As04)<br>$\Gamma_{p1}$<1 keV (2012As04)<br>%p: See also (2012Mu05, 2018Xu04, 2025Ni11).<br>E(level): From $E_{c.m.}$(p+$^{17}$Ne)=1550 keV *5*: Weighted average of 1552 keV *5* (2012As04), 1527 keV *25* (stat.) *20* (sys.) (2023Ch22), 1.55 MeV *7* (2012Mu05) and 1.53 MeV *2* (2025Ni11).<br>Γ: See also Γ=0.25 MeV *+25−15* (2012Mu05), Γ=22 keV *100* (2023Ch22) and Γ<40 keV (2025Ni11). |
| 466[eg] *45* | 0$^-$[b] | 300[cg] keV *100* | A E | %p=100 (2012As04,2025Ni11)<br>$\Gamma_{p0}$=300 keV *100* (2012As04)<br>$\Gamma_{p1}$<10 keV (2012As04)<br>XREF: E(0.59E3)<br>E(level): From $E_{c.m.}$(p+$^{17}$Ne)=1842 keV *40* (2012As04). |
| 654[eg] *28* | 1$^-$[b] | 900[cg] keV *100* | A E | %p=100 (2012As04)<br>$\Gamma_{p0}$=900 keV *100* (2012As04)<br>$\Gamma_{p1}$<100 keV (2012As04)<br>XREF: E(0.59E3)<br>E(level): From $E_{c.m.}$(p+$^{17}$Ne)=2030 keV *20* (2012As04). |
| 708[dg] *21* | 3$^-$[b] | 42[cg] keV *10* | AB DE | %p=100 (2012As04,2018Xu04,2023Ch22)<br>$\Gamma_{p0}$=42 keV *10* (2012As04)<br>$\Gamma_{p1}$<1 keV (2012As04)<br>XREF: E(0.59E3)<br>E(level): From $E_{c.m.}$(p+$^{17}$Ne)=2084 keV *5* (2012As04).<br>See also $E_{c.m.}$($^{17}$Ne+p)=2085 keV *23* (stat.) *20* (sys.) (2023Ch22).<br>Γ: See also Γ=84 keV *46* (2023Ch22), deduced from two-level Breit-Wigner analysis. |
| 1.1×10$^3$[h] *8* | | | D | %p=100 (2018Xu04)<br>E(level): From $E_{c.m.}$($^{17}$Ne+p)=2.5 MeV *+7−3* (2018Xu04).<br>E(level): This state suffers from a poor statistical significance (see Table I and Fig. 6 of 2018Xu04). But the existence of a level near $E_{c.m.}$($^{17}$Ne+p)=2.5 MeV was predicted by (2007Fo07: Theory). |
| 2.6×10$^3$[h] *16* | | | D | %p=100 (2018Xu04)<br>E(level): From $E_{c.m.}$($^{17}$Ne+p)=4.0 MeV *+15−6* (2018Xu04). |

[a] Excitation energies are reported with respect to $E_{c.m.}$(p+$^{17}$Ne)=1376 keV *20*, weighted average of 1.27 MeV *17* (2004Ze05), 1.23 MeV *15* (2012Mu05) and 1.38 MeV *2* (2025Ni11).
[b] From R-matrix analysis of (2012As04) using the Anar$\chi$ code.
[c] From $\Gamma=\Gamma_{p_0}$ (2012As04), deduced from R-matrix analysis.
[d] (2012As04, 2025Ch54) predict a configuration of $^{17}Ne_{g.s.}\otimes\pi d_{5/2}$ using shell model calculations for this state.
[e] (2012As04, 2025Ch54) predict a configuration of $^{17}Ne_{g.s.}\otimes\pi s_{1/2}$ using shell model calculations for this state.
[f] This state is reported to have a $^{17}$Ne*(1288, 3/2$^-$)$\otimes\pi d_{5/2}$ configuration.
[g] See also $E_{c.m.}$($^{17}$Ne+p)=1.97 MeV *2* and Γ=0.32 MeV *4* (2025Ni11) for an unresolved state that could contain contribution from this state.
[h] This state is suggested to be populated in the sequential proton decay of a newly observed $^{19}$Mg* state at $E_x$=8.9 MeV *+8−7* via the present $^{18}$Na intermediate state (2018Xu04).

## $^{1}H(^{17}Ne,p)$:res 2012As04

Resonant elastic scattering in inverse kinematics.
$J^{\pi}(^{1}H)=1/2^{+}$ and $J^{\pi}(^{17}Ne_{g.s.})=1/2^{-}$.
2011As07, 2011AsZX: XUNDL dataset compiled by TUNL, 2011.
The level structure of $^{18}$Na was studied by $^{17}$Ne+p resonant elastic scattering in inverse kinematics. A 4−MeV/nucleon $^{17}$Ne beam impinged on a 150 $\mu$m-thick polypropylene ($C_3H_6$) stopping target that was rotating at 1000 rpm at the GANIL spiral facility. Scattered protons were detected in either a cooled ΔE-E Si-Si(Li) telescope covering $\theta_{lab}=\pm2°$ or a CD-PAD position sensitive ΔE-E Si array covering $\theta_{lab}=5°-25°$. The laboratory $^{17}$Ne(p,p′) excitation function was deduced and converted to the center of mass using Monte Carlo simulations. This spectrum was analyzed using the Anar$\chi$ R-matrix code, from which parameters for 4 $^{18}$Na states were deduced: $^{18}Na_{g.s.}$ at $E_{c.m.}(^{17}Ne+p)$=1.54 MeV corresponding to a mass excess of ΔM=25.30 MeV *2* with $J^{\pi}=2^{-}$ and Γ=10 keV; $E_x(^{18}Na)$=320 keV with $J^{\pi}=1^{-}$ and Γ=500 keV; $E_x(^{18}Na)$=520 keV with $J^{\pi}=2^{-}$ and Γ=50 keV; and $E_x(^{18}Na)$=1400 keV with $J^{\pi}=3^{-}$ and Γ=700 keV.
The authors report a $J^{\pi}$ inversion for the ground and first excited states of $^{18}$Na when compared with the $^{18}$N mirror nucleus. No evidence is found for the lower-energy state reported by (2004Ze05).
2012As04: XUNDL dataset compiled by TUNL, 2012.
The authors repeated the previously described experiment optimizing the experimental setup and with the aim of improving the understanding of the dynamics of 2p decay of $^{19}$Mg.
A 4-MeV/nucleon $^{17}$Ne ion beam from the SPIRAL facility at GANIL impinged on a polypropylene ($C_3H_6$) target assembly. The target assembly consisted of a fixed 50 $\mu g/cm^2$ $C_3H_6$ foil followed by a rotating (1000 rpm) $C_3H_6$ foil with the same thickness, which stopped the beam and carried away the beam′s undesired decay radiation; scattered protons were unaffected by the target functionality.
The scattered protons, whose energies are convoluted with the target thicknesses and the scattering excitation function, were detected at $5°\leq\theta_{lab}\leq20°$ with an annular position sensitive ΔE-E telescope. The scattering excitation function, which is assumed to result from elastic scattering, is deduced with an energy resolution of 13 keV at FWHM in the center of mass. Small backgrounds from reactions on $^{12}$C and $\beta$-delayed protons from $^{17}$Ne are evaluated and subtracted from the proton energy spectrum. Finally the spectrum is evaluated via R-matrix analysis. Two peaks are prominent.
The deduced level structures are compared with shell-model predictions. Dimensionless reduced widths ($\theta^2$) are obtained. Interpretation suggests that the $1^{-}$ ground state and the $2^{-}_{2}$ excited state are too weakly populated and are too narrow to be observed in this experiment. These levels are predicted by the shell model to have a $^{17}$Ne*(1288, $3/2^{-}$)$\otimes\pi d_{5/2}$ configuration.

*Theory*:
2005Fo13, 2006Fo08: Using analysis of the mirror $^{18}$N system, frameworks are developed describing the low-lying levels of $^{18}$Na in terms of $^{19}$Na plus a neutron hole (2005Fo13) or $^{17}$Ne plus a proton (2006Fo08). Estimates on the mass excess and level spacing are discussed. (2007Fo07) found those low-lying states to have a *d*-wave configuration.
2012Fo10: The earlier approach used in (2005Fo13, 2006Fo08) was updated using newly available data. Calculated proton resonance energies, excitation energies, J, $\pi$, widths and spectroscopic factors. Comparison with experimental values.
2025Ch54: Investigated properties of $^{18}$Na and $^{18}$N mirror levels and the $^{17}$Ne(p,p) cross section using coupled-channel Gamow shell model. Good agreement is obtained with experimentally deduced (by 2012As04) energies and partial decay widths for the low-lying $^{18}$Na states. Isospin symmetry breaking between $^{18}$N-$^{18}$Na is discussed.

### $^{18}$Na Levels

(2012As04) did not observe the $^{18}Na_{g.s.}$ and the $^{18}Na^*(2^{-}_{2})$ state. They estimated $\Gamma_{p_0}<1$ keV and $\Gamma_{p_1}<1$ keV for the decays of those two unobserved states to the $^{17}Ne_{g.s.}$ and $^{17}$Ne*(1288, $3/2^{-}$), respectively. These unobserved states are reported to have a $^{17}$Ne*(1288, $3/2^{-}$)$\otimes\pi d_{5/2}$ configuration.
For theoretically deduced dimensionless reduced widths, see Table 1 in (2012As04). See also theoretical spectroscopic factors in (2012As04, 2012Fo10, 2025Ch54).

| E(level)[a] | $J^{\pi}$[f] | Γ[d] | $E_{c.m.}(p+^{17}Ne)$ (keV)[f] | Comments |
|---|---|---|---|---|
| 176[b] *21* | $2^{-}$ | 5 keV *3* | 1552 *5* | %p=100 (2012As04)<br>$\Gamma_{p0}$=5 keV *3* (2012As04)<br>$\Gamma_{p1}$<1 keV (2012As04) |

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**$^1$H($^{17}$Ne,p):res 2012As04 (continued)**

$^{18}$Na Levels (continued)

| E(level)[a] | $J^{\pi}$[f] | Γ[d] | $E_{c.m.}(p+^{17}Ne)$ (keV)[f] | Comments |
|---|---|---|---|---|
| | | | | E(level): Agrees with the theoretically deduced $E_x$=0.24 MeV *5* for the $2^-_1$ state from (2005Fo13: Theory), where $J^{\pi}$ was determined from mirror analysis.<br>$J^{\pi}$: The $J^{\pi}=1^-$ assignment for this peak is ruled out by R-matrix analysis in (2012As04). |
| 466[c] *45* | $0^-$ | 300 keV *100* | 1842 *40* | %p=100 (2012As04)<br>$\Gamma_{p0}$=300 keV *100* (2012As04)<br>$\Gamma_{p1}$<10 keV (2012As04) |
| 654[c] *28* | $1^-$ | 900[e] keV *100* | 2030 *20* | %p=100 (2012As04)<br>$\Gamma_{p0}$=900 keV *100* (2012As04)<br>$\Gamma_{p1}$<100 keV (2012As04) |
| 708[b] *21* | $3^-$ | 42 keV *10* | 2084 *5* | %p=100 (2012As04)<br>$\Gamma_{p0}$=42 keV *10* (2012As04)<br>$\Gamma_{p1}$<1 keV (2012As04) |

[a] From $E_{c.m.}(^{17}Ne+p)+S_p(^{18}Na)$, where $E_{c.m.}(^{17}Ne+p)$ is measured by (2012As04) and $S_p(^{18}Na)=-1376$ keV *20* (see the Adopted Levels).

[b] (2012As04, 2025Ch54) predict a configuration of $^{17}Ne_{g.s.}\otimes\pi d_{5/2}$ using shell model calculations for this state.

[c] (2012As04, 2025Ch54) predict a configuration of $^{17}Ne_{g.s.}\otimes\pi s_{1/2}$ using shell model calculations for this state.

[d] From $\Gamma\approx\Gamma_{p_0}$.

[e] Evaluator notes that a simple Monte Carlo simulation assuming $\Gamma_{p_0}$ as a Gaussian distribution with a mean of 900 keV and a standard deviation of 100 keV and $\Gamma_{p_1}$ as a uniform distribution from 0-100 resulted Γ=950 keV *104*.

[f] From R-matrix analysis in (2012As04) using the Anar$\chi$ code.

## $^{9}$Be($^{17}$Ne,$^{18}$Na) 2023Ch22

Proton pickup reaction using a fast beam.
$J^{\pi}(^{9}Be_{g.s.})=3/2^-$ and $J^{\pi}(^{17}Ne_{g.s.})=1/2^-$.
2023Ch22: XUNDL dataset compiled by TUNL, 2023.
The authors studied particle unbound states in a number of light nuclei, including $^{18}$Na. Previously published data include information on unbound states in other nuclei.
A cocktail beam of $^{15}$O (≈89% at E=48.1 MeV/nucleon) and $^{17}$Ne (≈11% at E=58.2 MeV/nucleon) was produced at the NSCL/A1900 by fragmenting a $^{20}$Ne beam. The beam impinged on a 1-mm-thick $^{9}$Be production target and populated short-lived $^{18}$Na levels that proton decayed before exiting the target. Complete kinematics measurement of the decay products was performed using the HiRA array comprising of 14 position sensitive Si-CsI(Tl) ΔE-E telescopes, which measured the charged-particle decay products covering $\theta_{lab}\approx2°-12°$. Based on published data on other nuclei, the telescopes were most likely arranged in vertical towers with a 2-3-4-3-2 configuration where the central tower had a gap between the upper and lower two telescopes to permit the beam a downstream exit at $\theta_{lab}=0°$. The CAESAR $\gamma$-ray array (158 CsI(Na) crystals) surrounded the target covering polar angles between $\theta_{lab}=57.5°-142.4°$. This array was used to measure the coincident $\gamma$-ray de-excitations, but no events were found in coincidence with $\gamma$ rays. In other words, the populated $^{18}$Na levels did not appear to decay to the $^{17}$Ne*(1288, 3/2$^-$) state.
The invariant mass spectrum indicates two peaks corresponding to the known $J^{\pi}=2^-_1$ and $3^-_1$ states at $E_x$~0.2 MeV and ~0.7 MeV (2012As04), respectively. These states are known to have a $^{17}Ne_{g.s.}\otimes\pi d_{5/2}$ configuration, which are favorably populated in the $^{9}$Be($^{17}$Ne,$^{18}$Na*→p+$^{17}Ne_{g.s.}$) proton pickup reaction. The configuration is confirmed by absence of $\gamma$-coincident events. The proton decay energy spectrum is fitted using two peaks with Breit-Wigner line shape to extract the level properties.

### $^{18}$Na Levels

All data are from (2023Ch22).

| E(level)[a] | $J^{\pi}$[b] | Γ[b] | $Q_p$ (MeV)[bc] | Comments |
|---|---|---|---|---|
| 151 *32* | 2$^-$ | | 1527 *25* | %p=100 (2023Ch22)<br>Γ=22 keV *+100−22* (2023Ch22)<br>Γ: (2023Ch22) reports Γ=22 keV *100*. Evaluator highlights that this value is consistent with zero. Therefore, it may suggest that the width is either not constrained by the fit, which seems unlikely as the peak is very prominent, or that the width is more likely dominated by the experimental resolution. If we interpret the 22- and 100-keV values as the expectation value and the square root of the variance of a log-normal distribution for the width of this state, respectively, then the median and factor uncertainty ($e^{\sigma}$) values will be 5 keV and $e^{\sigma}$=6, respectively. Also, the log-normal distribution becomes a peak-less distribution that resembles a Porter-Thomas distribution with a long tail, whose width is again consistent with zero.<br>Decays to $^{17}Ne_{g.s.}$ via proton emission (2023Ch22). |
| 709 *30* | 3$^-$ | 84 keV *46* | 2085 *23* | %p=100 (2023Ch22)<br>Decays to $^{17}Ne_{g.s.}$ via proton emission (2023Ch22). |

[a] From $E_{c.m.}$($^{17}$Ne+p)+$S_p$($^{18}$Na), where $S_p$($^{18}$Na)=−1376 keV *20* (see the Adopted Levels) and $Q_p=E_{c.m.}$($^{17}$Ne+p). We highlight that the uncertainties are statistical. A conservative systematic uncertainty of ΔE≈20 keV should be added in quadrature to these values.
[b] From a two-level Breit-Wigner line shape analysis. We note that it is unclear if the $J^{\pi}$ values were fit parameters, or if (2023Ch22) simply assigned the $J^{\pi}$ values from the previous R-matrix analysis by (2012As04).
[c] Proton decay energy in the $^{17}$Ne+p center−of−mass system.

## $^{9}$Be($^{20}$Mg,$^{18}$Na) at GANIL 2004Ze05

Neutron knockout reaction followed by proton decay from $^{19}$Mg.
$J^{\pi}(^{9}Be_{g.s.})=3/2^{-}$ and $J^{\pi}(^{20}Mg_{g.s.})=0^{+}$.

This dataset documents the experiment conducted at GANIL that is credited with the discovery of $^{18}$Na.

2004Ze05: A beam of 43-MeV/nucleon $^{20}$Mg ions was produced by fragmenting a $^{24}$Mg beam on a thick $^{12}$C target using the ALPHA spectrometer and SISSI solenoids at GANIL. The beam was transported to the SPEG spectrometer, where it impinged on a 47 mg/cm$^2$ $^{9}$Be foil placed in the spectrometer's target position. Light-ion ejectiles were detected in the position sensitive Si(Li)/CsI ΔE-E MUST array covering $\theta_{lab}=2°-25°$, while heavier decay fragments were detected in the spectrometer focal plane detectors covering $\theta_{lab}=\pm2°$. The invariant mass spectrum with a resolution of 250 keV *50* was generated for each of the p+$^{17}$Ne pairs observed in the experiment with a 150 keV systematic uncertainty. The resulting spectrum indicated two peaks that are attributed to proton decay from $^{18}$Na to $^{17}$Ne.

The two peaks are consistent with mass excesses of 24.19 MeV *16* and 25.04 MeV *17*. The interpretation of the two peaks remains unclear since no $\gamma$-ray detectors were used in the measurement; this missing information creates an ambiguity in interpretation for the case where a level in $^{18}$Na decays to an excited state of $^{17}$Ne. Significant discussion on the determination of the ground state level and assignment of $J^{\pi}$ values is given in the article.

The preferred analysis accepts the ground state mass excess of 25.04 MeV *17* with Γ=0.48 MeV *14* and $J^{\pi}=1^{-}$ (by comparison with the $^{18}$N mirror nucleus). This scenario assumes that $^{18}Na_{g.s.}$ decays to $^{17}Ne_{g.s.}$. The peak appearing in the invariant mass spectrum at 24.19 MeV *16* with Γ=0.23 MeV *10* is attributed to decay from an excited state of $^{18}$Na to the first excited state of $^{17}$Ne; in this case the experiment does not provide sufficient information to assign an excitation energy to the $^{18}$Na* level.

*Theory*:

2003Gr01: Calculated levels, J, $\pi$, configurations, radii using Cluster model. This study also suggested that the peak observed at $E_{c.m.}(p+^{17}Ne)\sim0.4$ MeV (see the Ph.D. thesis (2021) of the author of (2004Ze05)) is not the $^{18}Na_{g.s.}$ and may be due to decay of $^{18}$Na* to an excited state in $^{17}$Ne. (2003Gr01) reported that the $E_{c.m.}(p+^{17}Ne)\sim1.3$ MeV peak in that experiment is more likely to be the ground state. This study further discusses the role of $^{18}$Na states in the $^{19}$Mg 2p decay.

2005Fo13, 2006Fo08: Deduced mass excess of 25.06 MeV *13* for $^{18}Na_{g.s.}$ and calculated mass excesses and excitation energies of the low-lying states of $^{18}$Na, which are described using weak coupling and a simple Woods-Saxon potential model calculations guided by mirror analysis. These states are obtained in terms of $^{19}$Na plus a neutron hole (2005Fo13) or $^{17}$Ne plus a proton (2006Fo08). Estimates on level spacing are discussed. These studies attribute the $^{18}$Na state with ΔM=25.04 MeV from (2004Ze05) to an unresolved doublet from the decay of the ground and first excited states of $^{18}$Na to the $^{17}Ne_{g.s.}$. Furthermore, (2005Fo13) reports that the state with ΔM=24.19 from (2004Ze05) is primarily due to decay of a $(2_2^-)$ state at $E_x(^{18}Na)=0.60$ MeV *7* (deduced) to $^{17}$Ne*(1288, $3/2^-$). (2005Fo13) pointed out a peak near 25.9 MeV in the data of (2004Ze05), which was not analyzed, and attributed it to the decay of two or three states of $^{18}$Na (with $J^{\pi}=(3^-, 0^-$, and $1^-$)) to the $^{17}Ne_{g.s.}$.

### $^{18}$Na Levels

All data are from (2004Ze05) unless otherwise noted.

| E(level)[a] | $J^{\pi}$[d] | Γ | $E_{c.m.}(^{17}Ne+p)$ (MeV) | Comments |
|---|---|---|---|---|
| 0? | $(1^-)$ | 0.48[bc] MeV *14* | 1.27 *17* | %p≈100 (2004Ze05)<br>E(level): The state with a mass excess of ΔM=25.04 MeV *17* was assumed to be the ground state.<br>(2004Ze05) considered that this state decays by proton emission to $^{17}Ne_{g.s.}$.<br>The theoretical studies by (2005Fo13, 2006Fo08) report this state as an unresolved doublet consisting of the ground and first excited state of $^{18}$Na, both of which decay to the $^{17}Ne_{g.s.}$. |
| x? | | 0.23 MeV *10* | 0.42[e] *17* | %p≈100 (2004Ze05)<br>x=0.44 MeV (see the comments below).<br>E(level): A state with ΔM=24.19 MeV *16* is attributed to the |

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## $^{9}Be(^{20}Mg,^{18}Na)$ at GANIL **2004Ze05** (continued)

### $^{18}Na$ Levels (continued)

| E(level)[a] | Jπ[d] | Γ | $E_{c.m.}(^{17}Ne+p)$ (MeV) | Comments |
|---|---|---|---|---|
| | | | | proton decay from an excited state of $^{18}Na$ to the first excited state of $^{17}Ne$ at $E_x$=1288 keV. Under this assumption, the evaluator calculated $E_x(^{18}Na)=E_x(^{17}Ne^*)+\Delta M(^{18}Na^*)-\Delta M(^{18}Na_{g.s.})$=0.44 MeV. This value is also mentioned in (2005Fo13: Theory) and (2025Ni11: $^{9}Be(^{20}Mg,^{18}Na)$ at NSCL).<br>We highlight that (2012Mu05: $^{9}Be(^{20}Mg,^{18}Na)$ at GSI) found no evidence for the state with ΔM=24.19 MeV *16*. Later on, (2025Ni11) reports that this state does not belong to $^{18}Na$ and it originates from the prompt 2p democratic decay of the $^{19}Mg_{g.s.}$, where if only one proton is detected in coincidence with $^{17}Ne$, it would seem as if it is a state in $^{18}Na$. This is also the reason why this peak is absent in (2012Mu05) because the p-$^{17}Ne$ angular correlation in that study was obtained using a gate on the first excited state of $^{19}Mg$, which undergoes sequential 1p decay through some of the intermediate states of $^{18}Na$.<br>(2004Ze05) assumed that this state decays to $^{17}Ne^*(1288, 3/2^-)$+p. |

[a] From $E_{c.m.}(^{17}Ne+p)+S_p(^{18}Na)$, where $S_p(^{18}Na)=-1.27$ MeV *17* (2004Ze05).

[b] Evaluator notes that the theoretical discussion of (2005Fo13) reports immeasurably small widths for this state.

[c] Evaluator notes that NUBASE-2020 reports $T_{1/2}=1.3\times10^{-21}$ s *4* from (2004Ze05). This half-life corresponds to Γ=0.34 MeV *9*, which is the width of a $^{18}Na$ state with mass excess of ΔM=24.19 MeV *16*. Here, we note that (1) this width is corrected by those authors to Γ=0.23 MeV *10* after taking into account the experimental resolution of 250 keV *50* (2004Ze05). (2) Moreover, (2004Ze05) suggested that the state with ΔM=24.19 MeV is most likely an excited state. (2004Ze05) considered the $^{18}Na_{g.s.}$ to be a state with ΔM=25.04 MeV *17* and decay width of Γ=0.480 MeV *14*. (3) Finally, (2025Ni11: $^{9}Be(^{20}Mg,^{18}Na)$ at NSCL) reports that the state with ΔM=24.19 MeV does not belong to $^{18}Na$. It originates from the prompt 2p decay of the $^{19}Mg_{g.s.}$ to the $^{17}Ne_{g.s.}$.

[d] From mirror analysis. Therefore, evaluator considered the value tentative.

[e] Deduced by the evaluator from $S_p(^{18}Na_{g.s.})+\Delta M(^{18}Na^*)-\Delta M(^{18}Na_{g.s.})$, where $S_p$=1.27 MeV *17*, $\Delta M(^{18}Na^*)$=24.19 MeV and $\Delta M(^{18}Na_{g.s.})$=25.04 MeV from (2004Ze05).

## $^{9}$Be($^{20}$Mg,$^{18}$Na) at GSI 2012Mu05,2018Xu04

Neutron knockout reaction followed by proton decay from $^{19}$Mg.
$J^\pi(^{9}Be_{g.s.})=3/2^-$ and $J^\pi(^{20}Mg_{g.s.})=0^+$.

This dataset describes a series of experiments performed by more or less the same group at GSI. They measured the in-flight decay of proton unbound states in $^{19}$Mg and $^{18}$Na and focused on analysis of the $p_1$-$^{17}$Ne, $p_2$-$^{17}$Ne and $p_1$-$p_2$ particle correlations following population of the $^{19}$Mg* states and their subsequent sequential 2p decay through the intermediate levels in $^{18}$Na to the $^{17}Ne_{g.s.}$.

2008Mu13, 2012Mu05: XUNDL dataset compiled by TUNL, 2012.

A beam of $^{20}$Mg ions (produced by fragmenting a 450-MeV/A $^{24}$Mg beam) impinged on a 2 g/cm$^2$ $^{9}$Be target at the mid-plane of the FRS separator/spectrometer at GSI. The target was surrounded by an array of four position sensitive Si telescopes that measured the breakup charged particle angular correlations ($p_1$-$p_2$, $p_1$-$^{17}Ne_{g.s.}$ and $p_2$-$^{17}Ne_{g.s.}$). The $^{17}Ne_{g.s.}$ heavy decay residues were momentum analyzed by the second half of the FRS and identified at the final focal plane using ToF, B$\rho$ and $\Delta$E-E. Two prominent peaks appear in the p-$^{17}Ne_{g.s.}$ angular correlation distribution: First is a peak consistent with 2p decay of the $^{19}Mg_{g.s.}$ directly to $^{17}Ne_{g.s.}$ with $E_{c.m.}$($^{17}$Ne+2p)=0.75 MeV *5*; second is a peak corresponding to $^{19}$Mg excited states decaying sequentially through proton unbound states in $^{18}$Na.

The excited states in $^{19}$Mg appear as "arc bands" in the $\theta$($p_1$-$^{17}$Ne) vs. $\theta$($p_2$-$^{17}$Ne) angular correlation spectrum. Analysis of events along a fixed or constant radius provides details about the parent $^{19}$Mg state and the $^{18}$Na states populated in the sequential decay of the parent to $^{17}Ne_{g.s.}$+2p. Evidence for two states is visible in the spectrum. Monte Carlo simulations are used to extract "best fit" values for energies and widths of $^{19}$Mg and $^{18}$Na states. Arguments based on the extracted widths and the Wigner limits are used to constrain $J^\pi$ values.

2018Xu04: XUNDL dataset compiled by B. Singh (McMaster), 2018.

This is an experiment by the same group as (2012Mu05), where the authors restudied proton decay of $^{19}$Mg* levels via the intermediate $^{18}$Na levels to calibrate their detection system for measurements of heavier exotic nuclei. The experiment setup and analysis techniques were almost the same as (2012Mu05) using the same facility, except in (2018Xu04), the $^{20}$Mg beam was produced from fragmentation of a 685-MeV/nucleon $^{36}$Ar beam on a $^{9}$Be target.

The populated $^{19}$Mg* states were observed as "arc bands" in the $\theta$($p_1$-$^{17}$Ne) vs. $\theta$($p_2$-$^{17}$Ne) angular correlation spectrum. Analysis of events along a fixed or constant radius provides details about the parent $^{19}$Mg state and the $^{18}$Na daughters populated in the sequential decay to $^{17}Ne_{g.s.}$+2p. Evidences for one new excited state in $^{19}$Mg and two previously unknown states in $^{18}$Na were found.

2025Xu03: The 3p-unbound $^{20}$Al nucleus was discovered by this study. $^{20}$Al sequentially decays to $^{17}Ne_{g.s.}$+3p via $^{19}$Mg. (2025Xu03) analyzed the data of (2007Mu15: $^{9}$Be($^{20}$Mg,$^{19}$Mg)) obtained as part of the experimental campaign followed by (2012Mu05) at the GSI/FRS facility. (2025Xu03) investigated the by-product $^{9}$Be($^{20}$Mg,$^{20}$Al) charge exchange reaction channel and discovered $^{20}$Al via analysis of the $^{17}$Ne+3p decay products, which were measured in 4−fold coincidence. The $^{20}Al_{g.s.}$ and $^{20}$Al*(1.67 MeV) levels were discovered from reconstruction of the $^{17}$Ne-p-p and p-p-p angular correlations. The ground state decays to $^{19}Mg_{g.s.}$+p, while the 1.67−MeV level decays to $^{19}$Mg*(1.38 MeV)+p. The $^{19}Mg_{g.s.}$ democratically decays to $^{17}Ne_{g.s.}$+2p, and the $^{19}$Mg*(1.38 MeV) state subsequently decays via the $^{18}Na_{g.s.}$ intermediate level to $^{17}Ne_{g.s.}$+2p.

### $^{18}$Na Levels

All levels decay by proton emission to $^{17}Ne_{g.s.}$ (see Fig. 1 in 2012Mu05).

| E(level)[a] | $J^{\pi}$[e] | Γ[c] | $E_{c.m.}$($^{17}$Ne+p) (MeV) | Comments |
|---|---|---|---|---|
| 0 | ($1^-$) | <0.2[d] MeV | 1.23[f] *15* | %p=100 (2012Mu05,2018Xu04)<br>$J^\pi$: From shell model and mirror analysis in (2012As04, 2012Mu05).<br>$E_{c.m.}$($^{17}$Ne+p) (MeV): See also $E_{c.m.}$=1.23 MeV (2018Xu04).<br>ΔM=25.02 MeV *15* for the $^{18}Na_{g.s.}$ (2012Mu05). |
| 0.32×10$^3$ *16* | $2^-$ | 0.25[d] MeV *+25−15* | 1.55[f] *7* | %p=100 (2012Mu05,2018Xu04)<br>E(level): (2018Xu04) reports that fragmentation of |

Continued on next page (footnotes at end of table)

**$^{9}$Be($^{20}$Mg,$^{18}$Na) at GSI 2012Mu05,2018Xu04 (continued)**

$^{18}$Na Levels (continued)

| E(level)[a] | $J^{\pi}$[e] | $E_{c.m.}$($^{17}$Ne+p) (MeV) | Comments |
|---|---|---|---|
| | | | $^{20}$Mg may populate this state and that it may decay via $^{17}$Ne*(1288, 3/2$^-$) emitting a 0.26-MeV proton.<br>$E_{c.m.}$($^{17}$Ne+p) (MeV): See also 1.55 MeV (2018Xu04). |
| 0.85×10$^3$ | 3$^-$ | 2.084[gh] | %p=100 (2018Xu04)<br>E(level): This state was inconclusively observed in (2011AsZX); however, (2012Mu05) reports that including this $J^{\pi}$=3$^-$ state at Q(p+$^{17}$Ne)=2.084 MeV permits a quantitative reproduction of the $^{17}$Ne+p+p correlation spectra. Later on, (2012As04, 2018Xu04) confirmed the existence of this state. The statistical significance of this peak in (2018Xu04) is considerable, where signal is more than 3 times larger than the background (see Table I in 2018Xu04). |
| 1.3×10$^3$[b] *8* | | 2.5[h] *8* | %p=100 (2018Xu04)<br>E(level): This state suffers from a poor statistical significance (see Table I and Fig. 6 of 2018Xu04). But the existence of a level near $E_{c.m.}$(p+$^{17}$)=2.5 MeV was predicted by (2007Fo07: Theory).<br>$E_{c.m.}$($^{17}$Ne+p) (MeV): From $E_{c.m.}$($^{17}$Ne+p)=2.5 MeV *+7−3* (2018Xu04). |
| 2.8×10$^3$[b] *16* | | 4.0[h] *16* | %p=100 (2018Xu04)<br>$E_{c.m.}$($^{17}$Ne+p) (MeV): From $E_{c.m.}$($^{17}$Ne+p)=4.0 MeV *+15−6* (2018Xu04). |

[a] From $E_{c.m.}$($^{17}$Ne+p)+$S_p$($^{18}$Na), where $S_p$($^{18}$Na)=−1.23 MeV *9* (2012Mu05).

[b] Evidence of a new level is proposed by (2018Xu04). This state is suggested to be populated in the sequential proton decay of a newly observed $^{19}$Mg* state at $E_x$=8.9 MeV *+8−7* via the $^{18}$Na intermediate state (2018Xu04).

[c] From (2012Mu05).

[d] Evaluator notes that the theoretical discussion of (2005Fo13) reports an immeasurably small width for this state.

[e] From R-matrix analysis of (2012As04). (2012Mu05, 2018Xu04) suggested those values as firm, except for the ground state, which was considered tentative as it was not observed by (2012As04).

[f] From (2012Mu05).

[g] From (2011AsZX).

[h] From (2018Xu04).

## $^{9}$Be($^{20}$Mg,$^{18}$Na) at NSCL **2025Ni11**

Multi nucleon knockout reaction.
J$^{\pi}$($^{9}$Be$_{g.s.}$)=3/2$^{-}$ and J$^{\pi}$($^{20}$Mg$_{g.s.}$)=0$^{+}$.

This study focuses on determining the ground state of $^{18}$Na and finding the origin of the state observed by (2004Ze05: $^{9}$Be($^{20}$Mg,$^{18}$) at GANIL) that corresponds to ΔM=24.19 MeV. (2025Ni11) reconstructs the $^{18}$Na low-lying levels from the $^{17}$Ne+p decay events using the invariant mass technique.

2025Ni11: XUNDL dataset compiled by TUNL, 2025.
Fragmentation of a 170-MeV/nucleon $^{24}$Mg on a $^{9}$Be target at NSCL (MSU) produced a 103-MeV/nucleon $^{20}$Mg using the A1900 fragment separator. This beam bombarded a 1-mm-thick $^{9}$Be production target. $^{18}$Na levels were produced and immediately decayed to the $^{17}$Ne+p products. An array of position sensitive ΔE(Si)-E(CsI(Tl)) ring-shaped telescopes covering $\theta_{lab}$=1.2°−10.1° measured the decay protons. The E-detectors were arranged in two concentric rings. The trajectories of the $^{17}$Ne decay residues were measured on their way to the S800 spectrograph using an array of scintillating fibers. Those ions were then momentum analyzed by the S800 spectrograph and their energies were measured at the focal plane.
The $^{18}$Na decay energy spectrum was deduced using invariant mass analysis. They report that the state that was observed by (2004Ze05) corresponding to a mass excess of ΔM=24.19 MeV does not belong to $^{18}$Na. Instead, it originates from the prompt 2p democratic decay of the $^{19}$Mg$_{g.s.}$, where if only one proton is detected in coincidence with $^{17}$Ne, it would seem as if it is a state in $^{18}$Na. They explain why this state was not observed by the subsequent studies. The present decay energy spectrum shows a broad unresolved structure peaking at E$_{c.m.}$($^{17}$Ne+p)=1.5 MeV that resembles a doublet with a high energy shoulder. Using three-level Breit-Wigner line shapes convoluted with the experimental energy resolution, the level properties of $^{18}$Na were extracted.
The $^{18}$N-$^{18}$Na mirror levels are identified and their mirror symmetry and configurations are discussed. Systematics for the neutron separation energy indicate a persistence of the N=8 magicity.

### $^{18}$Na Levels

All data are from (2025Ni11), where the experimental resolution at FWHM varies from 200-250 keV.
The seniority quantum number, $\nu$, is defined as the number of neutrons or protons that are not coupled in pairs to angular momentum J=0 (G. Racah, Theory of complex spectra. III, Phys. Rev. 63 (1943) 367).

| E(level)[a] | J$^{\pi}$[c] | Γ[cd] | E$_{c.m.}$($^{17}$Ne+p) (MeV)[c] | Comments |
|---|---|---|---|---|
| 0[b] | 1$^{-}$ | <40[e] keV | 1.38 *2* | %p=100 (2025Ni11)<br>ΔM=25.17 MeV *2*.<br>(2025Ni11) suggests that this state has a $\nu$=3 proton seniority. |
| 0.15×10$^{3}$[b] *3* | 2$^{-}$ | <40[e] keV | 1.53 *2* | %p=100 (2025Ni11)<br>(2025Ni11) suggests that this state has a $\nu$=1 proton seniority. |
| 0.59×10$^{3}$ *3* | | 0.32 MeV *4* | 1.97 *2* | %p=100 (2025Ni11)<br>E(level): This state may be the unresolved triplet consisting of the known J$^{\pi}$=$0^-_1$, $1^-_2$ and $3^-_1$ states, while the contribution of the unobserved $^{18}$Na*($2^-_2$) state to this peak cannot be ruled out. |

[a] From E$_{c.m.}$($^{17}$Ne+p)+S$_p$($^{18}$Na), where S$_p$($^{18}$Na)=−1.38 MeV *2* (2025Ni11).
[b] This state has a $\pi(1d_{5/2})^3\otimes\nu 1p_{1/2}$ configuration.
[c] From a three-level Breit-Wigner line shape analysis. We note that it is unclear if the J$^{\pi}$ values were fit parameters, or if (2025Ni11) assigned the J$^{\pi}$ values from previous mirror/shell model analyses by (2004Ze05, 2012As04) for the ground state and from R-matrix analysis by (2012As04).
[d] Intrinsic width of the state.
[e] The observed width is consistent with the experimental resolution.

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